ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY W. H. MAW AND ALEX. RICHARDSON.

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EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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The Council do not bind themselves to accept the highest or any Tender. W 691

G. R.

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G. R.

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G. R.

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Length between perpendiculars	167 ft.
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Tonnage Register	402 about.
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Composite Construction Engines	Vertical triple expansion.
Indicated Horse Power	1200 estimated
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G. R.

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(d) Electric Dish Washing Machine, 3-Tank Type, complete with Motor, 230 Volts, D.C.
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For further particulars, Tender Forms and addresses for viewing, apply to the CONTROLLER, Furniture Section, Disposal Board, 18, Queen Anne's Gate, Westminster, S.W. 1. W 871

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The whole of Steam, Exhaust and Drain Pipes.
5-ton Overhead Travelling Crane.
The above plant is ready for immediate shipment, and can be seen fixed as left off work, and should be sold in one or more lots.
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G. R.

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Above lying at No. 1 National Filling Factory, Leeds.
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A RENSHELT ELECTRIC FURNACE, 20 cwt. capacity, with three 125 KW. Phœnix Alternators, Switchgear, and Licence to use same.
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HERBERT REED,
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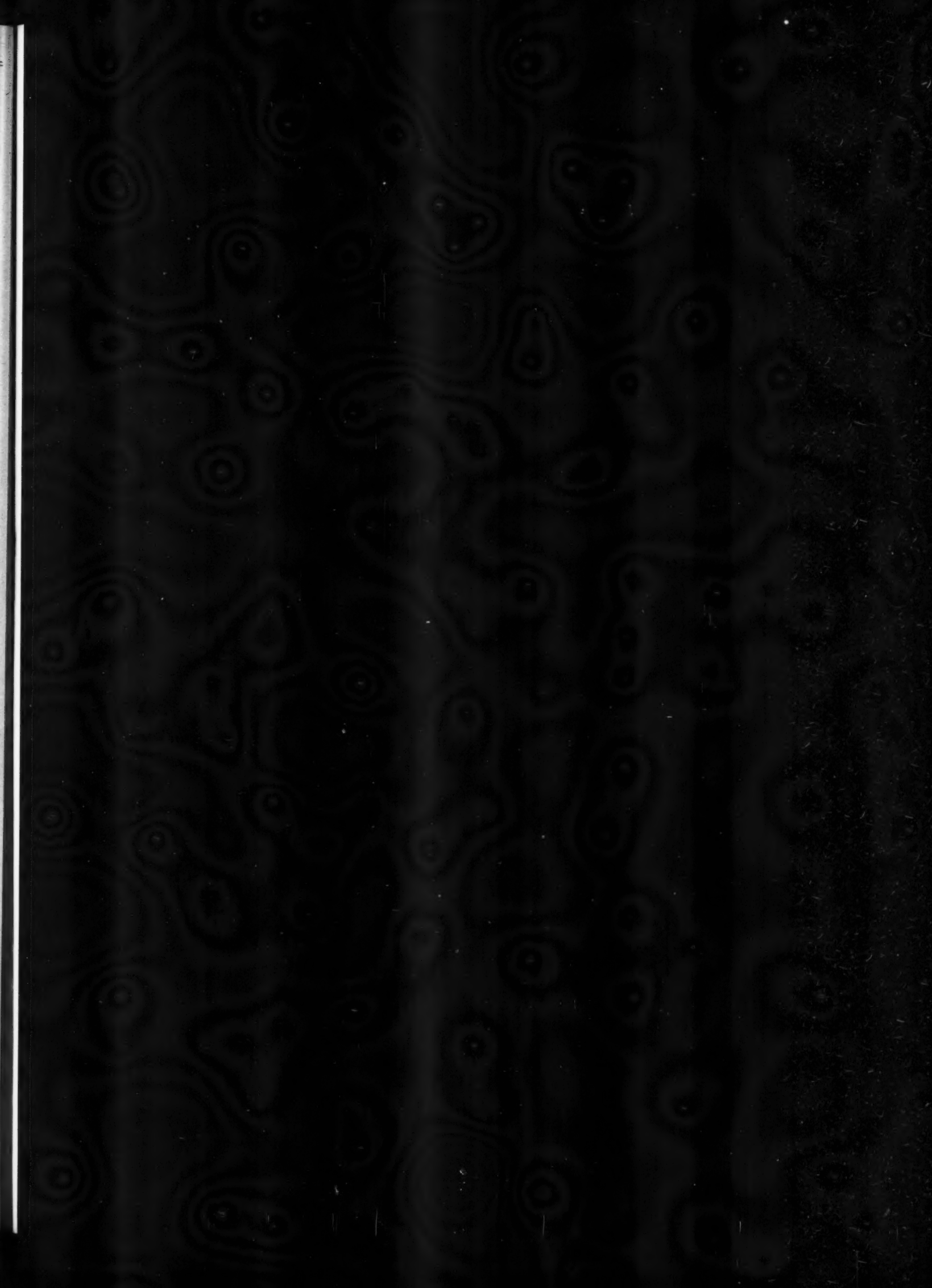
30th June, 1919. W 899



[JULY 4, 1919. VOL. CVIII.]

ENGINEERING.

THE HEAT TREATMENT OF GREY CAST IRON AT LOW TEMPERATURES.

By J. E. HURST.

THE question of the behaviour of commercial grey cast iron when subjected to prolonged exposure to heat in the low ranges of temperature below the lowest critical point is one of considerable industrial importance, and one upon which no adequate information has been published. Attention has already been drawn to the industrial aspects of the question in a symposium of papers before the American Society of Mechanical Engineers, December, 1909, dealing particularly with the effect of superheated steam on cast-iron fittings.* In these papers it was shown that commercial grey cast-iron when subjected to prolonged exposure to superheated steam in steam pipe lines at temperatures of 550 to 600 deg. F., experienced a considerable falling off in tensile strength and in addition a permanent expansion. Whilst these facts are fully substantiated there has been no attempt to explain the cause of the expansion or the falling off in strength. The reduction in tensile strength of cast-iron when tested at increasingly high temperatures from normal up to 800 deg. C. has been illustrated by Cary and Meyer.† This latter worker shows that the strength of cast-iron is reduced from 23·53 tons per square inch at 18 deg. C. to 12·09 tons per square inch at 620 deg. C. and to 7·56 tons per square inch at 807 deg. C.

Carpenter and Rugan in their classical work upon the growth of grey cast-irons noted an expansion at temperature of 650 deg. C. but considered that the phenomenon observed in superheated steam fittings was of a different nature to that of growth as investigated in their research. In a later publication (Part 6 of the paper) Professor Rugan in an investigation of the failure of a cast-iron steam separator which had been subjected to temperatures ranging from 370 to 470 deg. F. for a considerable period, observed that the disintegration similar to that observed in his earlier joint work with Professor Carpenter was to be found particularly on the inner surface of the casting which had been exposed to the action of the steam.

Other examples of the expansion phenomenon and the drop in tensile strength of grey cast-iron after having been subjected to the influence of heat at a comparatively low temperature are familiar in the form of automobile engine pistons and piston rings. There has, however, always been considerable doubt in these latter cases as to the actual temperature to which the articles have been exposed, and it is frequently assumed that the temperatures are usually very high. It is with these articles that the author is more intimately interested in the present article.

From our knowledge of the behaviour of steels it would be quite legitimate to assume that the expansions and reduction in tensile strength of cast-iron after exposure to low temperatures for considerable periods for the most part would be due to the removal of internal stresses set up in the casting during cooling and probably the growth of some of those crystals which are in any way subjected to such internal stresses. It will always, of course, be borne in mind that the occluded gases may play an additional and very considerable part in the phenomenon.

The question of the actual decomposition of the pearlite carbide at temperatures below the lowest critical point has never yet been definitely settled. In the generally accepted stable and meta-stable conception of the pure iron-carbon alloys it is considered that the stable phases in this range of temperature are iron (ferrite) and graphite, though it does not of necessity follow that the pearlite will actually dissociate within this range. No decomposition of the pearlite by prolonged annealing of steels within this range has yet been definitely proved.

Commercial cast-irons are complex alloys in which the position of the pearlite point is considerably modified by the presence of alloying elements. In the research on the iron-carbon-silicon alloys by Hague and Turner it was shown that the presence of silicon in pure-iron-carbon-silicon alloys resulted in a considerable raising of the pearlite point from 700 deg. C. in the alloy containing 0·3 per cent. to 795 deg. C. in the alloy containing 4·83 per cent. A corresponding increase in the temperature of the pearlite formation was also found by Gonterman, although the magnitude of the increase is different to that above named, a fact which might possibly be explained by the different experimental methods pursued. This rise in the transformation temperature has been alleged by Andrews to be in reality a rise in the Ar.2 point.

The presence of a small quantity of manganese 0·5 per cent. was shown by Hague and Turner to effect a considerable reduction in the temperature of the pearlite transformation from 774 deg. C. in the pure alloy to 687 deg. C. in the manganese alloy. This is very important, and illustrates the possibility of a considerable variation in the position of the pearlite point in actual commercial cast-irons. There appears however to be no doubt that the pearlite carbide does decompose at temperatures below the pearlite transformation on prolonged exposure to heat at these temperatures. Andrews in his "Carnegie Memoirs," previously quoted, shows that the thermal disturbance corresponding to the pearlite point on the cooling curve of a pure iron-carbon cast-iron is of considerable intensity, whilst on the heating curve the magnitude of the thermal transformation is considerably reduced. This is interpreted as indicating the decomposition of the pearlite carbide, whilst the temperature is being gradually raised up to the temperature of the pearlite transformation. A similar phenomenon was observed by Charpy and Grenet in the cooling and heating curves of a low silicon white iron.* In this curve the intensity of the two critical ranges in the cooling curve was reversed in the heating curve. It would also be gathered from Andrews' work that the silicon present has considerable influence upon the dissociation of the pearlite carbide below 700 deg. C., for in the heating curve of a normal pig-iron containing 2·45 per cent. of silicon and 0·45 per cent. of carbon the pearlite point is entirely absent.

Charpy and Grenet in the paper previously referred to show that in two samples of white cast-iron containing 1·25 per cent. and 2·10 per cent. of silicon respectively (the samples were retained in the white state by quenching in cold water) free carbon was found after exposure to a temperature of 650 deg. C. The sample containing 2·10 per cent. of silicon was found to contain 2·83 per cent. of free carbon (original total carbon 3·30 per cent.) after six hours' exposure at this latter temperature. Since Charpy and Grenet's samples only contained from 0·03 to 0·12 per cent. of manganese it is legitimate to conclude from Hague and Turner's work on the influence of silicon in cast-iron that the pearlite point would be considerably above the normal and probably in the region of 745 deg. C. Therefore, Charpy and Grenet's results would appear to show that in the presence of normally occurring quantities of silicon the carbide in cast-irons is capable of decomposition at temperatures considerably below the pearlite point. It is interesting to note that with only traces of silicon Charpy and Grenet did not obtain any precipitation of the carbon even after prolonged exposure to temperatures of 1,100 deg. C. It was found necessary to heat to 1,150 deg. C. for precipitation to take place. It was not stated by Charpy and Grenet whether it was the pearlite carbide or the cementite carbide which decomposed at this low temperature of 650 deg. C.

An interesting diagram has been recorded by Rolfe.† This diagram shows the effect of the annealing at various temperatures of grey cast-iron on the Brinell Scleroscope, tensile, and Stanton

* J. N. Hollis, A. S. Mann, E. F. Miller, *American Foundry*, January, 1910.
† *Stahl und Eisen*, Vol. XXVI.

* ENGINEERING, vol. lxxiii, page 626.
† Discussion on W. H. Hatfield's paper, read before the Royal Aeronautical Society, April 18, 1917.

repeated impact figures. The composition of the cast-iron is not stated, but it is presumed that it is a normal cast-iron used for the purpose of manufacturing aeroplane engine pistons, containing about 1·75 per cent. silicon. The manganese and phosphorus in this iron may be fairly high, but in any case it is safe to conclude that the position of the pearlite point will not be below 650 deg. C. An inspection of the curves shows that at a temperature of 550 deg. C. the Brinell hardness of the samples commences to show a marked decrease which is followed by a marked decrease in the scleroscope value and the tensile strength and simultaneously a marked increase in the resistance to repeated impact, which reaches a maximum at 600 deg. C. The Brinell figure apparently reaches a minimum at 700 deg. C. No chemical analyses are given, but the natural explanation of such a marked drop in the Brinell hardness from about 260 to 125 in the region of temperature round about 600 deg. C. would be that it is due to the decomposition of the pearlite carbide with the period of annealing at this degree of temperature. silicon members of the series whatever the original combined carbon contents.

It has been stated by Storey, from the results obtained from the investigation of the malleable cast-iron process, that it is impossible to bring about the decomposition of the pearlite carbide by prolonged annealing at temperatures below the lowest critical point. It will be remembered that malleable cast-irons are usually much lower in silicon than 1 per cent., and from the above results this statement would appear to be fully justified.

A series of impact tests were made on the above-mentioned specimens, both before and after heat-treatment. These experiments were carried out on an Izod impact testing machine of 120 ft.-lb. capacity, using a notched specimen of square cross-section. The results are given in the annexed Table IV.

It will be seen from these results that there is a general tendency towards an increased impact value after prolonged heat-treatment. The results on a tensile testpiece after subjection to the same prolonged heat-treatment are given below. The

TABLE IV.

Specimen No.	Impact Value before Heat-treatment.	Impact Value after Heat-treatment.
	ft.-lb.	ft.-lb.
0·0	6·00	8·0
2·0	6·25	—
3·12	5·75	7·5
4·15	6·00	10·0
5·10	4·75	5·0
6·13	4·75	9·5
7·16	4·75	5·5
8·14	4·75	6·5

Specimen.	Tensile Strength before Heat-treatment.	Tensile Strength after Heat-treatment.
B	tons per sq. in. 16·00	tons per sq. in. 13·88

The general increase in impact value accompanied by a drop in the tensile strength would appear to confirm the results of Rolfe previously mentioned.

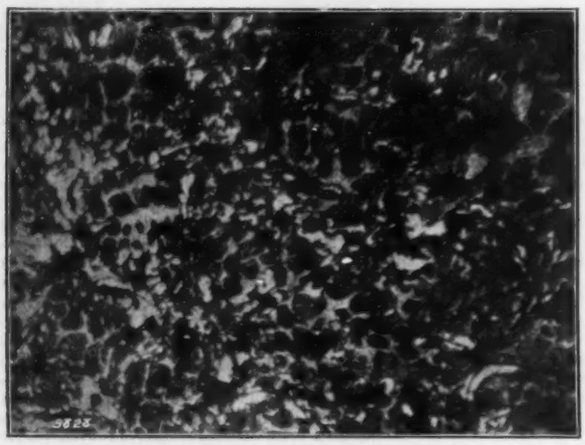


FIG. 1. AUTOMOBILE ENGINE PISTON; FROM GUDGEON PIN BOSS. ETCHED, AND MAGNIFIED 100 DIAMETERS.

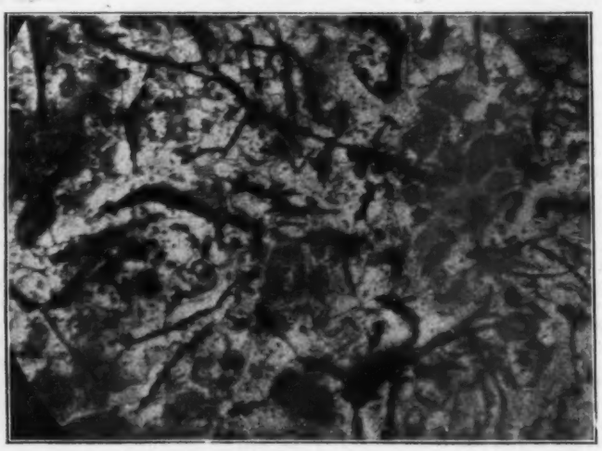


FIG. 2. AUTOMOBILE ENGINE PISTON; FROM CENTRE OF CROWN; AFFECTED BY THE HEAT. ETCHED, AND MAGNIFIED 100 DIAMETERS.

It is of considerable interest and importance to note the marked and decided increase in the Stanton repeated impact figures. These latter figures were obtained on the Stanton machine using ½ in. fall of tup and making 80 to 90 impacts per minute.

In the annexed tables the results are given of experiments upon the prolonged heat-treatment at temperatures of 575 to 600 deg. C. of a series of commercial cast-iron bars. The bars used in the experiments were ¾ in. square, the surface skin having been removed by planing down from the original 1 in. square section. The bars were heat-treated in a Fletcher gas muffle which was allowed to attain a constant temperature of 575 deg. C. over a period of two days before the specimens were introduced. In all cases after heat-treatment the specimens were allowed to cool slowly in the muffle.

The carbon determination has been accurately carried out and the figures given in the annexed tables are the average of six determinations. From these tables the assumption that prolonged heat-treatment at temperatures in the neighbourhood of the lowest critical point brings about a partial decomposition of the pearlite carbide is confirmed. There are two additional features which it is of considerable importance to notice. The first of these is that decomposition of the carbide is greater in extent in the higher silicon irons, being very nearly complete in those irons containing over 2 per cent. of silicon. In the lower silicon irons the extent of the decomposition was much less, and it would be reasonable to infer that in irons of less than 1 per cent. of silicon the decomposition would be still less. It is also of additional importance to note that the decomposition in the higher silicon members of the series reaches the same final value of combined carbon in the higher

TABLE I.—*Chemical Analysis (Before Heat-Treatment).*

Test No.	CC.	Gr.	Tot C.	Si.	Mn.	S.	P.
0·0	0·78	2·75	3·53	1·14	0·31	0·041	0·45
2·0	0·88	2·71	3·61	1·16	0·30	0·040	0·45
3·12	0·65	2·83	3·48	1·44	0·49	0·17	0·84
4·15	0·75	2·69	3·44	1·47	0·50	0·17	0·84
5·10	0·62	2·74	3·36	1·58	1·02	0·13	1·04
6·13	0·38	2·66	3·04	2·69	0·33	0·15	1·40
7·16	0·39	2·69	3·08	2·69	0·32	0·16	1·45
8·14	0·67	2·48	3·15	2·46	0·36	0·16	1·32

TABLE II.—*Analysis After Heat-Treatment for a Period of 150 hours.*

Test No.	CC.	Gr.	Tot C.
0·0	0·54	3·02	3·56
2·0	0·90	2·47	3·37
3·12	0·23	3·20	3·43
4·15	0·70	2·78	3·48
5·10	0·50	2·88	3·38
6·13	0·10	3·06	3·16
7·16	0·14	2·89	3·03
8·14	0·13	2·92	3·05

TABLE III.—*Brinell Tests: Before and After Heat-Treatment.*

Test No.	Before Heat-treatment.	After Heat-treatment. 72 Hours.	After Heat-treatment. 150 Hours.
0·0	212	202	207
2·0	228	228	196
3·12	228	170	223
4·15	228	223	207
5·10	255	187	217
6·13	179	170	196
7·16	207	187	217
8·14	241	187	170

results obtained show that there is a considerable drop in the tensile strength after heat-treatment.

TABLE V.

Specimen No.	Position of Measurement.	Before Heat-Treatment.	After Heat-Treatment (1)	After Heat-Treatment (2)	Maximum Total Expansion.	Remarks.
		in.	in.	in.	in.	
C.1	Length ..	1·740	1·750	1·748	0·010	
	End (1):					
	Breadth	0·4500	0·4520	0·4520	0·002	
	Thickness	0·4505	0·4520	0·4520	0·0015	
	End (2):					
	Breadth	0·4500	0·4510	0·4510	0·0010	
	Thickness	0·4505	0·4515	0·4515	0·0010	
C.3	Length ..	2·1120	2·120	2·120	0·008	
	End (1):					
	Breadth	0·44825	0·44975	0·44975	0·0015	
	Thickness	0·4495	0·4515	0·4515	0·002	
	End (2):					
	Breadth	0·4485	0·4525	0·4525	0·004	
	Thickness	0·4490	0·4510	0·4510	0·002	

The expansion does not appear to increase after 48 hours' treatment.

Heat-treatment (1) 48 hours at 550 deg. C.
" (2) Same specimens heated to same temperature for an additional period of 41 hours.

Another very important and interesting feature of these experiments is the measurement of the expansion of cast-iron after prolonged exposure at a temperature of 550—600 deg. C. The results of some measurements of this expansion are given in Table V. It will be seen on examination of these figures that the heat-treated specimens have undergone a considerable expansion in all directions. The approximate average percentage dimensional increase is about 0·35 per cent. From Table V. it will be seen that a further increase in the heat-treatment period of 41 hours produces no further expansion.

This expansion is presumably brought about for the most part by the precipitation of free carbon. It is highly probable, however, that this is not the

sole cause contributing to the total expansion, and it is the author's opinion that the occluded gases also play some part.

The results of these experiments fully justify the conclusion that the combined carbon in commercial grey cast-irons is gradually decomposed on subjection to prolonged heat-treatment at temperatures in the neighbourhood of 550 to 600 deg. C. It is also legitimate to draw the conclusion that the extent of this decomposition in a given time is independent of the initial quantity of combined carbon present in the cast-iron. The liability and extent of the decomposition would appear to depend upon the amount of silicon present in the iron, and in the present state of our knowledge it would appear that in those irons with silicon contents not higher than 1 per cent. the decomposition will be extremely difficult to bring about.

An additional and very important feature is the marked increase in the impact value after prolonged annealing at these temperatures. It is within the author's knowledge that it is the practice in certain quarters to anneal gas engine pistons at temperatures of 450 deg. C., possibly with the object in view of relieving internal stresses due to casting. In the light of Rolfe's experiments and those of the author this procedure would appear to be inadvisable, and if annealing is resorted to at all it would be better to carry it out at temperatures of from 550 to 600 deg. C. It is important also to bear in mind that in view of the expansions noted above it is highly improbable that any advantage from the standpoint of release of internal stresses is gained. More, rather, one would expect the internal stresses to be increased by such a treatment.

This question of the behaviour of cast-iron when subjected to temperatures below the lowest critical point is one of considerable commercial importance particularly from the point of view of automobile engine piston and cylinder construction. The actual temperature attained during running of cast-iron automobile engine piston heads is undoubtedly in the neighbourhood of 500 deg. C., although in many cases the temperature attained is much higher than this. Working under admittedly defective conditions the temperature attained may be as high as 600 to 650 deg. C. The microstructure of a motor car piston taken respectively from the gudgeon pin boss, a portion not directly exposed to the action of the heat, and from the centre of the piston head is illustrated in Figs. 1 and 2, page 2. The extensive decomposition of the combined pearlite carbide in the portion exposed to the action of the heat is amply illustrated. This actual piston failed through the formation of cracks in the crown. The composition of the piston was as follows :—

	Per Cent.
C. C.	0·50
Gr.	2·78
Total C.	3·30
Si.	2·10
Mn.	0·68
S	0·08
P	1·25

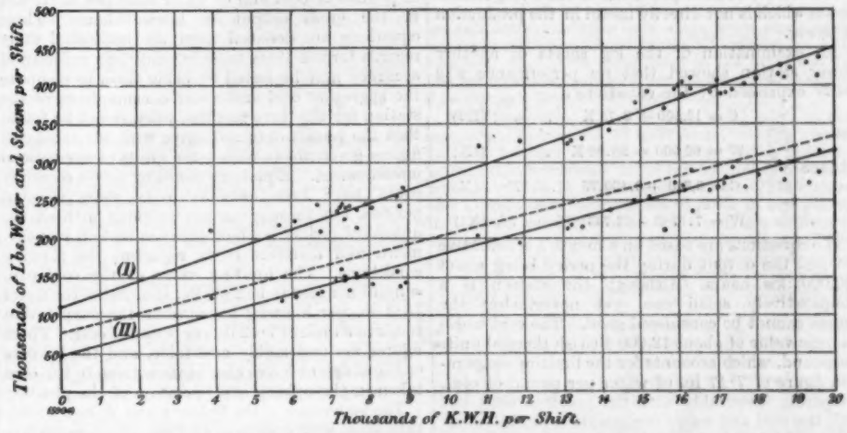
Analysis taken from neighbourhood of Gudgeon Pin Boss.

The silicon content of this material would lead one to anticipate the extensive decomposition of the carbide, and it is probably through the local deposition of free carbon in the crown, causing internal stresses that the cracking, the cause of failure of the piston, was brought about. It would appear desirable therefore that cast-iron for automobile pistons should contain a much lower silicon content 1 per cent. or below. With extreme care and careful selection of irons a perfectly machinable cast-iron can be produced with this low silicon content. The other alternative would be to produce a cast-iron containing practically no combined carbon. This would necessitate a high silicon content, and doubtless considerable trouble would be experienced owing to the coarseness of the graphite in such irons when produced as sand castings. Such irons would be relatively weak and porous. It is possible, however, to produce high silicon castings having a very low combined carbon without possessing coarse graphite structures by the use of metal permanent moulds. There would appear to be a field for the development of cast-iron permanent mould castings in this connection.

STEAM AND COAL CONSUMPTION IN POWER STATIONS.

By R. H. PARSONS, M.E.I.C.

PROBABLY every central station engineer has been worried at some time or another over the discrepancy between the quantity of water he has to pump into his boilers and the quantity of steam his main generators would consume if they operated at their guaranteed efficiency. The difference, after allowing what may be considered a reasonable amount of steam for the operation of the auxiliary machinery and for other known sources of loss is apt to be accounted for by saying that the main units cannot be operating with anything like the efficiencies which they showed on test. No one is really satisfied by this explanation. Reciprocating engines unquestionably do deteriorate in economy in course of time, but the unaccounted-for steam is usually far more than could justly be laid at the door of the worst possible engine. Moreover, modern plants are equipped almost exclusively with turbines and the claim of turbine builders that their machines do not sensibly deteriorate with use appears to be substantiated, at any rate in the case of the reaction type.



In order to arrive at some definite figures showing what the missing steam amounts to, and how it varies with the output of the plant, the records of a certain station were analysed and the results proved of considerable interest. The station in question was of the modern type containing water-tube boilers with chain-grate stokers, economisers and superheaters. The turbine equipment had an aggregate rated capacity of about 6,000 kw., and the net output of the station was about 12,000,000 kw.-h. per annum, of which practically one-sixth was supplied as direct current for traction, being converted by means of motor generators. All auxiliary machinery with the exception of the coal conveyor and the circulating water pump was steam driven.

The period chosen for analysis was from January 16 to January 31, 1919, because during that time the load was carried by a single turbine running day and night. The data were abstracted from the log sheets on file so that they fairly represent the conditions obtaining when the operation of the station was not under special observation. It is possible that somewhat greater consistency might have been obtained had figures been collected expressly for the purpose in view, but the results would then have lost all the value attaching to their present innocence of any suspicion of manipulation. No attempt has been made to correct any reading which appeared to be of doubtful value.

To study the steam and water consumptions of the station, the method described in ENGINEERING of November 14, 1914, was adopted. A diagram was prepared on which the feed water used per shift, and the steam taken by the turbine per shift were plotted against the corresponding gross outputs of the generator. The result is shown in the engraving above. Through each series of plotted points a straight line has been drawn, the upper line, marked I, representing the average feed-water consumption for all outputs per shift, and the lower line, marked II, giving the average steam consumption of the turbine. The steam consumption figures were obtained from an integrating Lea recorder in continuous use on the discharge of the condensate pump.

The equation to the upper line (I) is :

$$W = 110{,}000 + 17\,K \quad . \quad . \quad . \quad (I)$$

in which W represents the pounds of feed water pumped into the boiler per shift, and K denotes the gross output of the machine in kilowatt-hours per shift. The lower line (II) is represented by the equation :

$$S = 48{,}000 + 13.35\,K \quad . \quad . \quad . \quad (II)$$

Where S denotes the pounds of steam taken by the turbine per shift, and K is the output as before.

The difference between these two equations, or :

$$W - S = 62{,}000 + 3.65\,K \quad . \quad . \quad (III)$$

is obviously a statement of the water or steam taken by auxiliaries, lost by blowing-off, leakage, condensation, &c. In this particular case a certain amount of steam was used for heating the buildings, but even allowing for this, it will be clear how very serious an item the missing steam is in the economy of the plant.

Since we have taken our missing steam as the difference between the steam actually used in the turbine and the amount of the boiler feed, the quantity is obviously not affected in any way by the question as to whether or not the turbine was living up to its guaranteed efficiency.

The machine from which the records are taken is of the reaction type and had been running practically continuously for five years without being opened. Its original guaranteed consumption with a 28-in. vacuum may be represented over the load in question with very great accuracy by the Willans line :

$$G = 76{,}800 + 12.8\,K \quad . \quad . \quad . \quad (IV)$$

In which G is the guaranteed total steam consumption per shift, and K, as before, denotes the output per shift. This line passes accurately through the guaranteed consumptions at half, three-quarter and full load. It is shown dotted in the annexed diagram, and it will be seen on reference that the actual turbine performance is apparently considerably better than the guarantee. At half load (12,800 kw.-hours per shift) the guaranteed figure is improved on to the extent of 9·04 per cent., at three-quarter load the difference is 5·65 per cent., and at full load it would amount to 3·63 per cent. It should be noted, however, that the guarantees were based on a 28-in. vacuum, whereas during the period under review the circulating water was almost at freezing-point, and the vacuum was rarely worse than 29 in. and frequently considerably better. Nevertheless, it is reasonably clear that the turbine had suffered no appreciable loss in efficiency during its prolonged service.

The facts so far considered point to two conclusions. Firstly, the margin for improvement in economy, so far as main generators are concerned is almost insignificant in comparison with the field which exists for reducing steam consumption elsewhere in a power station; and secondly that

barring mechanical injury, a steam turbine may retain its efficiency indefinitely.

The coal consumption of the station with which we have been dealing, is given by the equation:

$$C = 21{,}000 + 2.9\,K \quad . \quad . \quad . \quad (V)$$

Where C shows the number of pounds of coal burnt per shift and K is the output as before. This equation was obtained by plotting the coal consumption figures against the output per shift, exactly as in the case of the water. The apparently high coal consumption is not only due in a great measure to the "missing steam," but the figures must be regarded in the light of the fact that the coal is a low grade of lignite, and in no way comparable to British coal. Eliminating K from equations I and V we have:

$$C = 2{,}235 + 0.17\,W \quad . \quad . \quad . \quad (VI)$$

or

$$W = 5.86\,C - 13{,}103 \quad . \quad . \quad (VII)$$

These equations indicate that the evaporation will approach a limiting value of 5·86 lb. of water per pound of coal, and that were no water to be used per shift, it would take 2235 lb. of coal per shift to maintain steam pressure. From equation V we see that at no output the station would consume 21,000 lb. of coal per shift, so that the difference, or 18,765 lb. of coal per shift, is used to generate steam which is not directly useful in the production of power.

An examination of the log sheets of another power station showed that its performance was fairly expressed by the equations:

$$C = 12{,}500 + 3.75\,K \quad . \quad . \quad (VIII)$$

and

$$W = 66\,000 + 26.92\,K \quad . \quad . \quad (IX)$$

whence

$$C = 3{,}306 + 0.139\,W \quad . \quad . \quad (X)$$

or

$$W = 7.17\,C - 23{,}733 \quad . \quad . \quad (XI)$$

The equations are based on a month's consecutive records, the output during the period being about 520,000 kw.-hours. Although the station is a comparatively small one, yet nevertheless the figures cannot be considered good. The coal had a calorific value of about 12,000 British thermal units per pound, which accounts for the limiting evaporation figure of 7·17 lb. of water per pound of coal, comparing favourably with the previous case, but both the coal and water consumption per kilowatt-hour are high. In fact, it looks as if the feed water consumption of the station must be something like double the guaranteed steam consumption of the main generators. These latter are of the impulse type, and the conditions are such that they are probably taking much more than the guaranteed amount of steam.

The best all-round performance of any small power station which has yet come to the notice of the writer is that of the municipal plant of the City of Regina, Canada, the engineer and manager of which is Mr. E. W. Bull. The following figures summarise results of the operation of this station for the last three consecutive months, for which the records are complete at the time of writing:—

	Output.	Coal.	Feed Water.
	kw.-hours.	lb.	lb.
February, 1919	1,113,550	3,098,600	21,779,700
March, 1919	1,156,500	3,298,500	24,129,500
April, 1919	1,028,520	3,067,500	21,503,200
Total	3,298,570	9,464,600	67,412,400

—	Feb., 1919.	March, 1919.	April, 1919.	Average.
Pounds coal per kilowatt-hour	2·78	2·85	2·98	2·87
Pounds water per kilowatt hour	19·55	20·86	20·9	20·44

The output given in the first column of the table above is the aggregate output of the main generators. Of this output, 3,102,580 kw.-hours were delivered as alternating current; the balance, amounting to 5·95 per cent., was used in the station for driving auxiliaries, lighting, &c. Of the alternating current delivered, 927,800 kw.-hours or, say, 30 per cent., was converted to direct current and used for traction purposes. The total losses in transmission lines, transformers, meters, &c., on the alternating-current system vary from 6·9 per cent. to 10 per cent. of the current leaving the power house. The higher figures for coal and water consumption towards the end of the period covered by the table are explained by certain adverse operating conditions. It may be added that the coal consumption of this station has been kept below 2·5 lb. per kilowatt-hour for weeks together. The fuel used is a bituminous coal with a calorific value of about 12,400 British thermal units per pound and carrying ash and moisture to the extent of 16 per cent. and 1·5 per cent., respectively. The weight of furnace refuse averages 20 per cent. of that of the coal fired, and daily calorimeter tests are made both on coal and refuse.

The coal and water equations of the station are as follow:—

$$C = 10{,}000 + 2.06\,K$$

and

$$W = 60{,}000 + 15.3\,K$$

whence

$$C = 0.134\,W + 1921$$

or

$$W = 7.42\,C - 14272$$

in which C and W respectively represent the number of pounds of coal and of water used per shift, and K the gross output in kilowatt-hours. These equations are deduced from the individual daily records for the three months, and their substantial accuracy may be tested by using them to compute the aggregate coal and water consumptions of the station for the three months, when it will be found that the results obtained agree with the tabulated figures given above within the limits of commercial measurement. Equations denoting better economy could have been obtained over short selected periods, but those given are weighted with all the untoward incidents which occur in station management, and therefore fairly represent the running conditions. The limiting value of the coal consumption is seen to be 2·06 lb., and that of the water 15·3 lb. per kilowatt-hour, while the evaporation tends to a limit of 7·42 lb. per pound of coal. These figures are undeniably creditable, and the lowness of the constant losses also bears witness to the care taken in the upkeep and operation of the plant.

The boilers are of the Babcock and Wilcox water-tube type, with underfeed stokers. Each boiler has 4,928 sq. ft. of heating surface and is equipped with an economiser of 2,300 sq. ft. and a superheater of 730 sq. ft. surface. The working pressure is 200 lb. per square inch and the average temperature of the steam is 540 deg. F. The greatest possible care is taken to avoid losses either of steam or heat. In addition to the main economisers mentioned, Mr. Bull has installed in the boiler flue a low-pressure economiser through which the condensate water is first pumped. Thence the water passes to a heater constructed of four old boiler drums connected together and placed also in the main flue. This heater has a capacity of 100,000 lb. of water, and into it are led all drains from steam pipes, traps, &c., the superheater blow-offs and the safety valve blow-offs. The feed water, in consequence, reaches the main economisers at a temperature of about 140 deg. F., and the flue gases at the base of the stack are rarely higher in temperature than 220 deg. F.

The engine-room equipment comprises three Willans and Robinson turbines, two of which are rated at 1,500 kw. and the third at 3,000 kw. A Lea recorder enables checks upon steam consumption to be readily made and condenser leakage to be discovered. The surface condensers are large and are equipped with Parsons' vacuum augmentors and Edwards' air pumps. The heated air from the main generators is taken to the boiler room and used by means of motor-driven fans to provide hot forced draught for the stokers. Mr. Bull finds a distinct economy to result from this arrangement, and in any case it serves to mitigate the excessive engine-room temperature often found in turbine stations.

Auxiliary machinery of every kind is motor driven with the exception of the boiler feed pumps and the induced-draught fans. Steam exciters and steam stoker engines are provided in case of need, but are never used in ordinary circumstances. There is thus practically no exhaust steam available for feed-water heating, the heat in the flue gases being utilised for this purpose to the fullest extent.

A further point of interest in this station is the provision for make-up feed water. The water supply to the station is hard and somewhat alkaline, and therefore unsuitable for use in boilers. Instead of installing a softener, Mr. Bull decided to take every care to conserve his water, and to provide for the small losses which are inevitable by evaporation. A live steam evaporator is employed and the evaporated water is condensed in the heater, thereby returning the heat of evaporation to the system. The amount of make up water only averages about 3·75 per cent. of the total feed, and as the water is absolutely pure the usual blowing-off of boilers is entirely dispensed with, a considerable saving both of water and of heat being thereby effected.

SADI CARNOT.

By Engineer-Commander EDGAR C. SMITH, R.N.

THAT Carnot in his famous memoir "Reflexions sui la puissance motrice du feu" adopted the caloric or material theory of heat is well known. According to this theory heat was supposed to be "a subtle elastic fluid which permeated the pores of bodies and filled the interstices between the molecules of matter." Caloric could not be created; neither could it be destroyed. The amount of heat entering the condenser was the same as that which entered the engine with the steam. Carnot's essay appeared in 1824. His death eight years later, at the age of 36, robbed the scientific world not only of an original and profound thinker but also of a man of wide sympathies and great versatility. For a quarter of a century or more after Carnot's death the caloric theory held sway among physicists and engineers, and the attitude of engineers towards the new doctrine of the mechanical theory of heat was the subject of some interesting remarks by Sir Dugald Clerk in his presidential address to the Engineering Section of the British Association in 1908.* The "Reflexions" was the only work Carnot published. It attracted but little attention at the time, and it was not reprinted till 1871 when it appeared in the "Annales Scientifique de l'École Normale Supérieure." Carnot's brother, Hippolyte issued another edition in 1878, publishing with it a portrait, a short biography and a collection of notes from Sadi's manuscripts. From these it was seen that Carnot not only was aware of the objections to the caloric theory, but that he had grasped the important principle of the equivalence of heat and work. Indeed, there can be little doubt that had he lived a few years longer he would himself have established the science of thermodynamics and have forestalled much of the work of Mayer and Joule. It is not often a memoir nearly a hundred years old provides the subject of a paper to-day, but Carnot's work still retains its scientific and historical interest and his views on the equivalence of heat and work were again recently brought before the Paris Academy of Sciences by L. Décombe.

Carnot came of one of the most celebrated families of Burgundy. His father was none other than Lazare Nicolas Marguerite Carnot the mathematician, engineer, revolutionist and administrator who, after serving his country faithfully during the stormy times of the revolutionary period, died in exile in Magdeburg in 1823. A pupil of Monge, the creator of descriptive geometry, the elder Carnot early made a name as a mathematician, but when the Revolution broke out he threw himself heart and soul into politics. It was he who, when France was surrounded by enemies, organised the 14 armies for which Berthollet, Monge and Chaptal provided the munitions. In Carlyle's "French Revolution" will be found the story of Carnot's escape from the guillotine by the accidental discovery of a list of proscribed names in Robespierre's coat pocket. Carnot married in 1786 and his first son he named Sadi, after a noted Persian poet and moralist of the thirteenth century whose writings he admired. He lost this child in infancy, but when another son was born he did not hesitate to call him, also, Sadi, the boy's full name being Nicolas Leonard Sadi

* ENGINEERING, September 4, 1908.

Carnot. There was a third son called Hippolyte, while Carnot's grandson—Marie François Sadi Carnot—was the President of the French Republic who was assassinated at Lyons, June 24, 1894. Sadi Carnot, the physicist, was born June 1, 1796, in the Luxembourg Palace, where his father then lived as a member of the Directory. As a boy he was somewhat delicate, but with time he grew stronger, and after attending the Lycée Charlemagne in 1812 he entered the École Polytechnique, where he had for a fellow student the geometer Chasles. His progress was rapid, and in 1813 he secured the first place for the artillery, but being judged too young for the school at Metz he was permitted to remain at the École Polytechnique for another year. This was how he came to take part with the other students in the defence of Paris in March, 1814. Among his papers was found their address to the Emperor Napoleon, December 29, 1813 :—

Sire, la patrie a besoin de tous ses défenseurs ; les élèves de l'Ecole Polytechnique, fidèles à leur devise, demandent de voler aux frontières pour partager la gloire des braves qui se dévouent au salut de la France. Le bataillon, fier d'avoir contribué à la défaite des ennemis, reviendra dans cette enceinte cultiver les sciences et se préparer à de nouveaux services.

In October, 1814, he passed into the Corps of Engineers, at Metz, and the next few years were spent in ordinary routine duties in various garrisons where, in the words of his brother, he was employed "compter des briques, réparer des pans de murailles et lever des plans destinés á s'enfouir dans les cartons." In 1819 he availed himself of the opportunity to enter the staff corps in Paris, and there nearly all the remainder of his life was spent. Continuing the studies which had originally begun under the tuition of his father, he followed courses at the College de France, the Sorbonne and elsewhere, studied music, natural history and political economy, and found time to inspect the factories and workshops of Paris. "Son intelligence insatiable ne lui permettait d'ailleurs de rester étranger à aucune branche du savoir." In 1826 he became a captain in the Corps of Engineers, and retired from the service for good the following year, taking advantage of his leisure to visit some of the principal centres of industry. The Revolution of 1830 interrupted his studies somewhat, but not for long. Excessive application, however, led to ill-health. An attack of scarlet fever was followed by brain fever, from which he was slowly recovering when he fell a victim to the epidemic of cholera which cost Paris the lives of some 18,000 inhabitants. He died August 24, 1832.

Published by Bachelier, in Paris, the "Reflexions sur la Puissance motrice du Feu et sur les machines propres a développer cette puissance" may be regarded as one of the classics of physical science. This "epoch-making gift to science," as Kelvin called it, seems to have hardly escaped oblivion. Had it not been for Clapeyron (1799–1864), the able French railway engineer, it might possibly have been lost sight of altogether. Clapeyron, also an "ancien élève" of the Ecole Polytechnique, had been to Russia with Lamé (1795–1870) for some years, and on his return turned his attention to the steam engine and railway engineering. In 1834 he published in the Journal of the Ecole Polytechnique a paper entitled "Sur la Theorie mecanique de la chaleur," in which he commented on the ideas of Carnot. This was the essay which fell into the hands of Kelvin in 1845 while a student working in the laboratory of Regnault (1810–1878). So little was Carnot's memoir known that it was three years before Kelvin obtained a copy, eventually receiving one from Professor Lewis Gordon, the predecessor of Rankin at Glasgow.

In 1847 Kelvin met Joule. The result is indelibly written in the history of science. The period 1848 to 1856, Sir Oliver Lodge considers, was when Kelvin was at his greatest. "Mastering the facts emanating from Carnot and Joule with an astounding keenness and penetration, surpassing even Helmholtz, Kelvin had elicited the most beautiful discoveries concerning the conservation of energy and the comprehension of the laws of thermodynamics, discoveries whose charm we could hardly understand now."* Of Joule and Carnot, Kelvin himself remarked when unveiling a statue of the former at Manchester in 1893, "Joule's initial work was the very foundation of our knowledge of the steam engine and steam power. Taken along with Carnot's work it gave the scientific foundation on which all the great improvements since the year 1850 had been worked out not in a haphazard way but on a careful philosophical basis."

It was the absence of any sound theory regarding the steam engine which led to Carnot's investigations. His views on the importance of the matter are stated in the early part of his memoir :—

Personne n'ignore que la chaleur peut être la cause du mouvement qu'elle possède même une grande puissance motrice ; les machines à vapeur, aujourd'hui si répaudues, en sont une preuve parlait à tous les yeux . . .

L'etude de ces machines est du plus haut intérêt, leur importance est immense, leur emploi s'accroit tous les jours ; elles paraissent destinées a produire une grande révolution dans le monde civilisé.

In the year which will see the commemoration of the centenary of James Watt it is not without interest to recall Carnot's tribute to England as the home of the steam engine :—

Si l'honneur d'une découverte appartient à la nation ou elle a acquis tous son accroissement, tous ses developpements, cet honneur ne peut être ici refusé à l'Angleterre : Savery, Newcomen, Smeaton, le celèbre Watt, Woolf, Trevethick et quelques autres ingénieurs anglais sont les veritable créateurs de la machine à feu ; elle a acquis entre leurs mains tous ses degrés successifs de perfectionnement . . .

But, he continued,—

Malgre les travaux de tous genres entrepris sur les machines à feu, malgre l'etat satisfaisant ou elles sont aujourd'hui parvenues, leur theorie est fort peu avancée, et les essais améliorations tentes sur elles sont encore dirigés presque au hasard.

Carnot's general views on the phenomena of heat may be gauged from the following brief extracts from his note books :—

La chaleur n'est autre chose que la puissance motrice, ou plutôt que le mouvement qui a changé de forme. C'est un mouvement dans les particules des corps. Partout où il y a destruction de puissance motrice, il y a eu même temps, production de chaleur en quantité précisément proportionelle à la quantité de puissance motrice détruite. Reciproquement, partout ou il y a destruction de chaleur il y a production de puissance motrice. . . .

D'après quelques idées que je me suis formées sur la theorie de la chaleur, la production d'une unité de puissance motrice nécessite la destruction de 2·70 unites de chaleur.

The unit Carnot used was the work necessary to raise 1 cub. metre of water 1 metre high. His equivalent is therefore equal to $\frac{1,000}{2 \cdot 70} = 370$ kg.-m. Mayer gave the value 365 in 1842, while Joule's equivalent for many years was 425 kg.-m. Among the experiments Carnot proposed to make were these :—

Répetér l'expérience de Rumford, sur le forage d'un metal dans l'eau mais measurer la puissance motrice consommée en même temps que la chaleur produite ; mêmes expériences sur plusieurs métaux et sur le bois. . . .

Agiter fortement de l'eau dans un barillet ou dans un corps de pompe à double effet et dont le piston serait percé d'une petite ouverture.

Expérience du même genre sur l'agitation du mercure, de l'alcool, de l'air et d'autres gaz. Mesurers la puissance motrice consommée et la chaleur produite.

Carnot work was no exception to the rule that the great majority of scientific discoveries have been made by men still young. This rule might be illustrated by a long list of names, such as Newton, Huyghens, Black, Adams, Leverrier, Hertz, Rontgen, Perkin and Davy. In an age of great scientific activity, thermodynamics was founded by a new and rising generation which included Mayer, Joule, Kelvin, Helmholtz, Clausius and Rankine. When the mathematician Roger Cotes died, in 1716, at the age of 33, he left a series of unfinished researches on optics which caused Newton to say, "If Mr. Cotes had lived we should have known something." A somewhat similar remark might have been made of Carnot, but whereas the science of optics received but few additions during the eighteenth century, within twenty years of Carnot's death the new branch of physics with which his name is so intimately connected was firmly established and numbered among its adherents some of the greatest names in the scientific history of the nineteenth century.

* Sir Oliver Lodge's Presidential address to Faraday Society, see ENGINEERING, May 29, 1908, page 722.

PISTON VALVE LEAKAGE.

WE are indebted to Mr. J. T. Wallis, the general superintendent of motive power, to the Pennsylvania Railway Company, for the following interesting account of experiments made at Altoona to determine the leakage of steam past the piston valves of locomotives :—

An investigation of the leakage of piston valves for locomotives has been conducted by the test department of the Pennsylvania Railroad at Altoona over a period of years, and has only recently been concluded. The apparatus used in the tests, consisted of a horizontal steam chest or valve chamber in which a full-size valve could be operated ; an electric motor for driving the valve ; control apparatus for the speed and length of valve travel ; a surface condenser to condense steam which leaked past the valve so that it could be weighed ; a steam generator, consisting of a locomotive standing near the test machine ; a separately-fired superheater ; steam gauges, thermometers, water weighing tanks, &c.

The valve testing machine, while following much the same lines as an earlier one, was made so that valves of different diameters could be tested. It is shown by the illustrations, Figs. 1 to 4, on page 6. The valve chamber proper consisted of a bushing or liner inserted in the machine in such a way as to form a space for steam jacketing. These liners could be easily removed from the machine, and were made with diameters of 12 in. and 14 in., some had a plain or smooth interior surface and some were made with pockets or shallow blank ports. It cannot be said, however, that these ports acted in the same way as the ports in a locomotive where large volumes of steam flow through them to the cylinders.

When the valve uncovered these blank ports on the steam side they would fill with steam, and this steam, trapped between the valve and the valve chamber walls, would be released on the exhaust side of the valve when it moved in the reverse direction. Thus there was a quantity of steam in the exhaust, in addition to that which leaked past the rings, and, this additional weight of steam was estimated from the volume of the ports or pockets and the pressure and specific volume of the steam. The leakage past the valve always greatly exceeded this correction for steam passed through the ports.

With some of the valve chambers, in order to save work in machining a whole new casting when a new inner surface only was required, thin liners or bushings, much like steam chest bushings, were pressed in. These liners were ¾ in. thick, and the ports were cut through them, making the ports ¾ in. deep. They were bored to 12 in. diameter after being pressed into place in the main valve chamber and, at first, were used without being sealed against leakage between the two surfaces. Later, as an extra precaution, the corners of the pockets and the outside ends of the liners were welded to the valve chamber. There were no indications, however, from the results obtained, that would indicate that the bushings were leaking before they were welded.

The steam was admitted to the valve chamber and valve at the centre of the machine, and the steam which leaked past the valve was led off from each end, separately, to a condenser which was in two parts. The condensed steam flowed from the condenser into two weighing tanks. The steam jacket was drained at the centre, into a steam trap, so that it was kept filled with live steam.

The valve was driven by an electric motor of 5 h.p. having adjustable speed control. The valve travel could be changed, and for the tests it was decided to use three travels, 1¼ in., 3¾ in., and 5¾ in., as representing about one-quarter, one-half, and three-quarters of the valve travel of 7 in., which is the maximum on our locomotives.

Lubrication.—In all of the tests with saturated steam, a hydrostatic sight feed lubricator was used, and it fed oil into the steam pipe just above the connection to the valve test machine. After some trials with reduced oil feed, it was found that about three drops per minute was the minimum that would ensure good lubrication and prevent excessive wear of rings and bushing.

When superheated steam was first used, the same method of feeding oil and a rate of three drops per minute was continued, and the same valve rings used as were used with saturated steam. For a few tests no lubrication trouble developed, and when the valve was removed it was found to be in good condition. When new rings and a new bushing were tried with superheated steam, however, using the hydrostatic lubricator, excessive steam leakage developed, and when removed the valve was found to be entirely dry, and the bushing and rings badly cut. Forced feed or oil-pump lubrication was then substituted for the other, for use with superheated steam, with oil inlets at each end of the bushing, at the top and at the centre of travel of each pair of valve rings. This method of

APPARATUS FOR TESTING PISTON VALVE LEAKAGE AT ALTOONA.

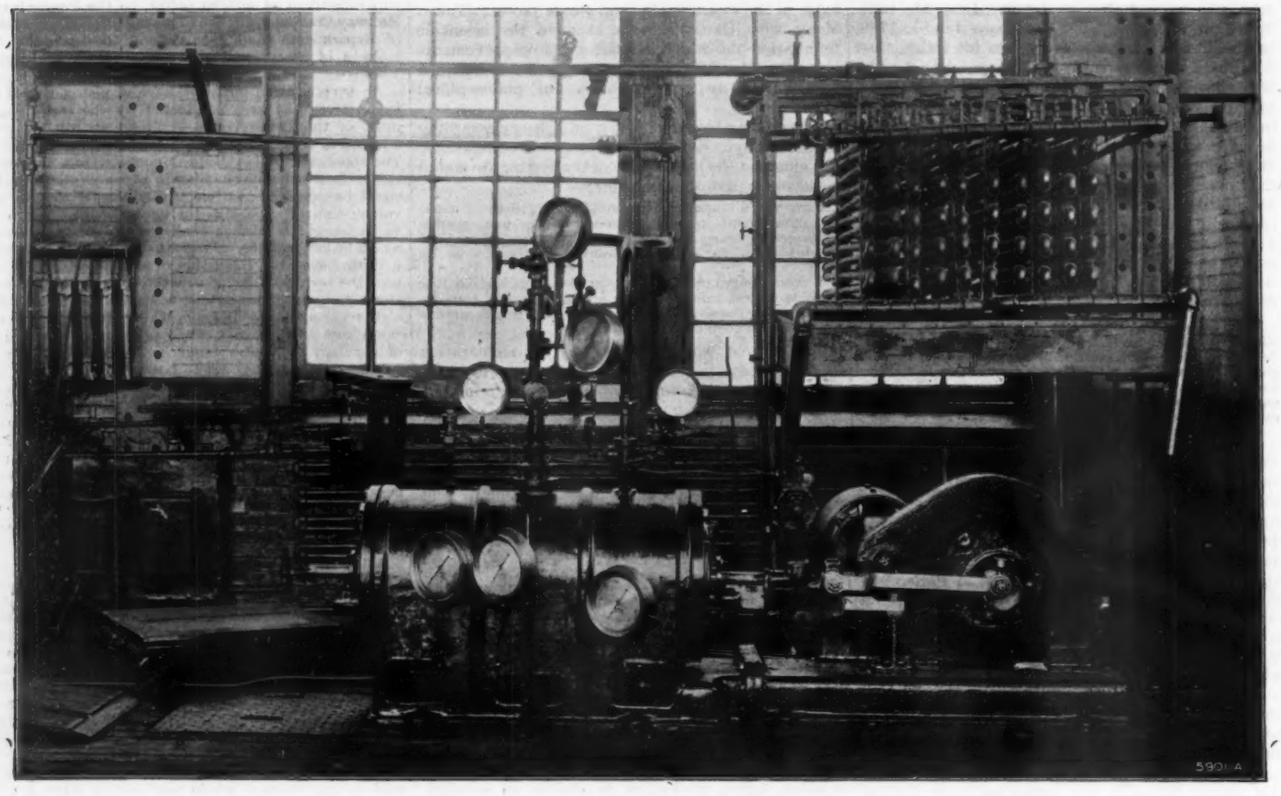
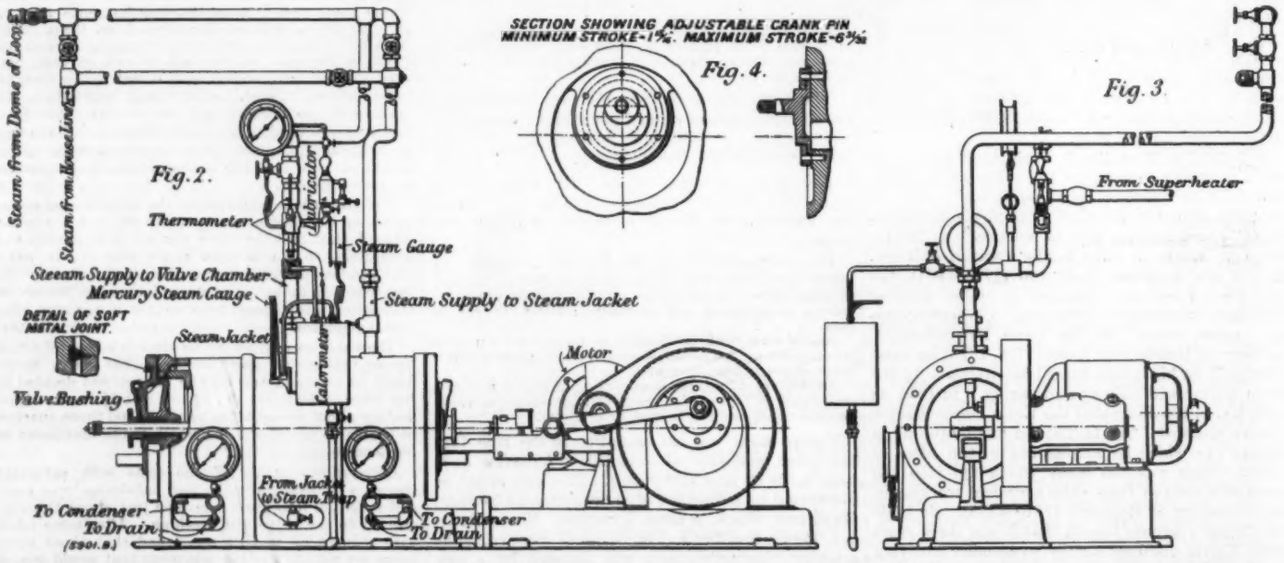


FIG. 1.



lubrication was continued in all superheated steam tests, and was fairly satisfactory.

It appears that there was enough oil on the bushing and valve to lubricate the rings in the first tests with superheated steam, but that the hydrostatic lubricator failed to supply any oil in a form that could reach the wearing surfaces when using superheated steam, and when these surfaces were renewed, lubrication failed entirely.

It must be borne in mind, however, that the lubrication of the valve in these tests had but a slight relation to the lubrication in the actual locomotive, because of the very small volume of steam flowing through the machine and carrying oil to the wearing surfaces. The tests with superheated steam were very destructive to the ring surface. None of the rings had a smooth polished surface after the tests, but in all cases they were cut and scored.

Method of Conducting Tests.—The general method employed in conducting the valve tests was to run the machine under fixed conditions of steam pressure and temperature, speed and travel of valve for 1 hour, making observations of pressures, temperatures, speed and weight of steam leakage, at intervals of 10 minutes throughout the run.

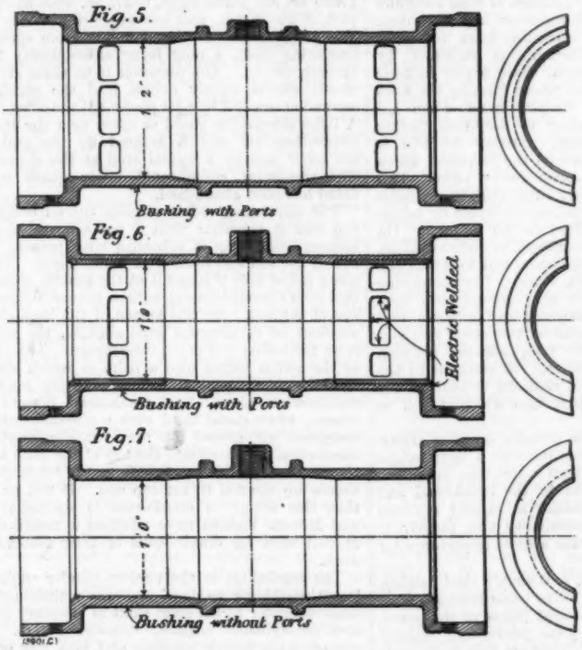
Speed of Valve.—The valve machine was operated at speeds of 80, 120, 160, 200, 240, 280 and 320 r.p.m.

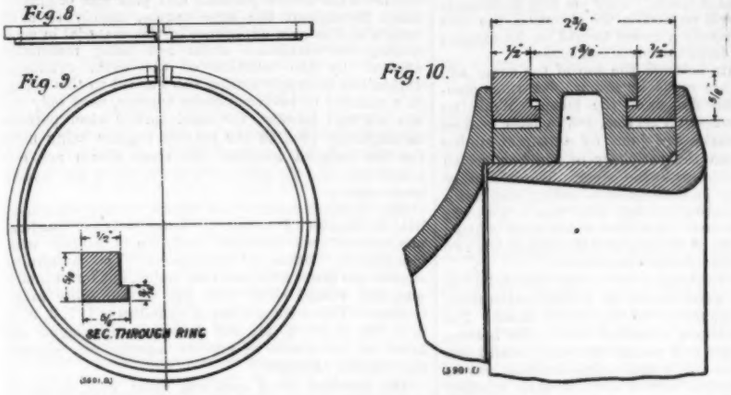
Steam Pressure.—The steam pressure was 205 lb. per square inch on the boiler, and somewhat less at the testing machine, but usually not less than 185 lb. In the ordinary operation of a locomotive, the steam chest pressure is considerably below the boiler pressure, and in these tests, the actual steam pressure conditions of our locomotives were approximated.

Saturated Steam.—When using saturated steam, the steam pipe connections were direct from the boiler to the valve testing machine, and about 60 ft. in length. A steam calorimeter was attached just above the steam entrance to the machine, and a correction for quality was made.

Superheated Steam.—For the superheated steam tests, the steam was passed through a separately-fired superheater having two locomotive superheater elements coupled together in series, and heated by an oil flame. The steam pressure and temperature were observed at the outlet from the superheater, at the entrance to the valve-testing machine and at an outlet from the side of the steam space in the machine.

APPARATUS FOR TESTING PISTON VALVE LEAKAGE AT ALTOONA.





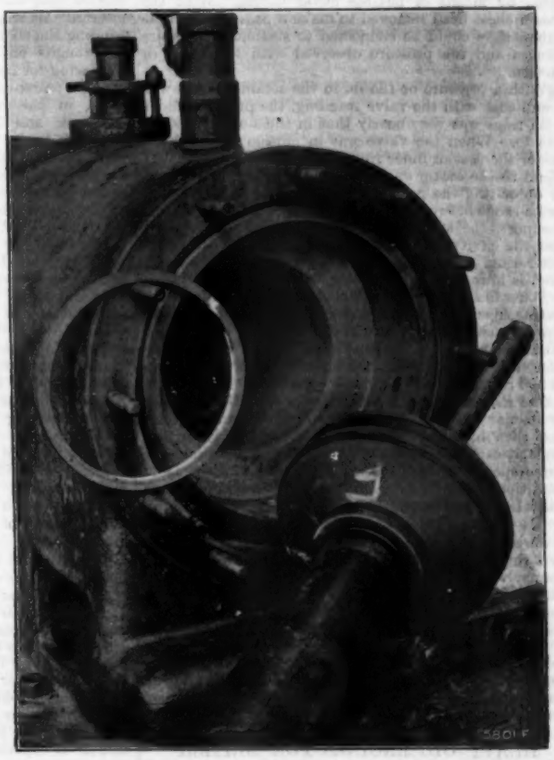


FIG. 11.

FIG. 12.

But two valve sizes were used, a few tests being made with a 14-in. valve, but nearly all with a valve 12 in. in diameter. The Pennsylvania Railroad valve rings were from regular stock, and had no special preparation. Some special forms of ring were also used. The valve body, for most of the tests, was of the older Pennsylvania Railroad type, but in a number of tests with plain bushings the late form of light-weight valve for the class E.6s locomotive was used. The ring joint was of the step or lap form in most cases, but some rings with a diagonal joint were tested. (See Figs. 8 to 10, annexed.)

Valve rings were tested with saturated steam, and with steam having a superheat of 100 deg., 200 deg. and 300 deg. There were thin metal diaphragms in the ends of the valve to prevent steam flowing through the valve body. A $\frac{1}{16}$ in. hole was drilled in one of these diaphragms so that the interior of the valve would be under exhaust steam pressure.

Leakage. General Statement.—The results in steam leakage were erratic, but, taking account of all that appeared normal, and those where the present standard two (2) ring valve, with a diameter of 12 in. was used in the plain bushing, the leakage at each end of the valve ranges between 171 lb. and 183 lb. per hour with saturated steam; between 194 lb. and 210 lb. with steam at 100 deg. superheat; between 181 lb. and 197 lb. with steam at 200 deg. superheat; and between 122 lb. and 132 lb. with steam at 300 deg. superheat.

For the bushing with ports, the tests show a leakage of between 302 lb. and 326 lb. per hour for saturated steam, between 425 lb. and 448 lb. per hour for 100 deg. superheat, and between 383 lb. and 414 lb. per hour for 200 deg. superheat.

Valve Travel.—The length of valve travel, when it ranged between 2 in. and 6 in., was found to have but little effect upon the leakage.

Speed.—The speed of the valve (strokes per minute) had no appreciable effect upon leakage.

Form of Ring Joint.—No difference in leakage was found between the step and diagonal form of ring joint.

Rings with Large Side Clearance.—The side play of the ring in the grooves of the valve, when made according to our locomotive maintenance instructions, is between 3 thousandths and 8 thousandths of an inch, and the valves were made up in this way. It was noted, however, that in some cases there was a tendency for the ring to be clamped or pinched in the grooves at the joint, but free at other points.

To determine the effect of rings loose in the grooves, a trial was made with rings having a side clearance of about $\frac{1}{16}$ in. The results of this trial were that the rings having the large side play show somewhat less leakage than the same rings when a close fit in the grooves. The leakage was 190 lb. per hour for the standard width and 186 lb. for the loose rings.

Steam Pressure under Rings.—The pressure under

the valve rings was measured with the valve standing and also when it was in motion. The pressure gauges were connected to the spaces under the inner and outer rings by means of flexible metal tubing. With the steam chest head removed to make a passage for these tubes, they could be connected to stationary pressure gauges and the pressure observed with the valve in motion.

With a pressure of 185 lb. in the steam chest it was found that with the valve standing, the pressure under both rings was very nearly that in the steam chest, or 185 lb. When the valve was in motion the pressure under the first or inner ring was a steady pressure and equal to the steam chest pressure. Under the second or outer ring the pressure was a fluctuating one, and had a range between 90 lb. and 150 lb. In passing over the port, the steam under the outer ring is released and the cavity refilled by steam which leaks past the inner ring. The pressure, therefore, under the outer ring, is lower than that under the inner ring.

Power to Drive Valve.—The electric drive of the valve-testing machine made it possible to measure the gross power consumed in operating the machine. The motor is rated at 5 h.p., but this rated power was greatly exceeded, and as much as 15 h.p. was observed in tests at 300 r.p.m.

One Ring Valve.—In one series of tests the two-ring or regular valve was first tried in the plain bushing, and then had both inner rings removed. With two rings at each end of the valve, the average leakage for three speeds was 186 lb. per hour and under the same conditions, but with one ring at each end the leakage was 418 lb. per hour. This is an increase of 232 lb., or 124 per cent.

Three-Ring Valve.—One valve had three instead of two rings at each end, and these rings were of the Pennsylvania Railroad Anchor type. Except for the added ring, this valve was the same as the valve with two rings, and it was expected that the third ring would make a tighter valve form than the two-ring. Except in one series of tests the leakage with the three-ring valve was less than with two rings. The improvement appeared to be small, however, in view of the added complication of the third ring, or four extra rings per locomotive.

HEAVY OIL ENGINES FOR BRITISH SUBMARINE BOATS.

IN our issue of February 28 last we gave photographs and descriptions of the Vickers' submarine engines, and we are now in a position to supplement these by drawings showing the construction of two typical engines and by particulars of trial results.

The twelve-cylinder engine is one that has been made in large numbers during the war by Messrs. Vickers, both at their works at Barrow-in-Furness and at Ipswich. It has also been manufactured by a number of firms working under licence from Messrs. Vickers. The latter firm has latterly introduced various improvements in detail and in arrangement of controls, and as these, owing to the necessity of rapid production, were not wholly incorporated in the engines made by licensed firms, who were working to Admiralty instructions, the description we now append will include points interesting even to those who are fully conversant with the earlier engines. This twelve-cylinder engine is shown in elevation in Fig. 1, Plate I, while a cross-section is given in Fig. 2 of the same Plate.

The peculiar framing construction of the engines is plainly evidenced by these drawings. First of all it will be noticed that each main bearing is carried by a separate steel casting, and these castings are recessed into longitudinal beams, athwartship fitted bolts, not shown in the drawing, tying the two together. This construction obviously entails considerable care in chocking the engines in the boat, but with trained workmen no difficulty arises, and the required accuracy is obtained in a surprisingly short time. In adaptations of these engines when weight was relatively unimportant, a cast bedplate has been substituted, and a similar design carried out in steel is, with modern foundry methods, applicable to the light weight engines, and would probably be proposed for future work where interchangeability with previous parts, as for Admiralty work, is not important. In this respect, as in many other points in the engine, some of which will be subsequently mentioned, the designers have been handicapped by their own success, as improvements which experience has pointed out to the firm were sometimes not acceptable on account of the necessity of maintaining uniformity with the large number of engines already in commission.

The columns consist of boiler plate somewhat less than $\frac{1}{16}$ in. in thickness. At the top is a forged steel head into which the column plate is rabetted, three rows of rivets securing the head to the column plate. The plate is cut with lightening holes, and at the bottom is branched by a slot cut for removal of the main bearing cap. To the lower extremities of these branches are riveted four forgings, forming the feet. These are of approximately triangular elevation, and are plainly visible in the sectional view. The riveting of the heads and feet of the columns is most carefully carried out, the holes being reamered and the rivets inserted alternately from opposite sides to avoid bending the column. The column is stiffened by light angles on its outer edges, these angles forming the facing for light sheet steel plates forming the sides of the crank-case. Small circular hand doors are fitted in the outboard casing to facilitate feeling the liner and lower bearings. Further stiffness is given by angles plainly shown on the elevation which support the horizontal tie-plate below them. This tie-plate has a hole in it slightly larger than the cylinder jacket bottom flange, and supports the latter by means of four adjustable snugs bolted to the tie-plate. On the column head is placed a sandwich or distance-piece, which takes the weight of the liner, and to which the cover is secured by six $1\frac{1}{4}$-in. studs. The connecting joint consists of a cast-iron ring ground into both liner and cover. The main impulse load is transmitted from the covers to the columns by two studs and four bolts, $1\frac{1}{8}$ in. diameter, for each column between adjacent cylinders, two bolts only in addition to the studs being fitted to the end columns of each of the four groups of three cylinders, into which it will be noted the engine is divided.

This framing construction permits of close determination of stresses and lends itself to a light-weight engine, but the main practical advantage is in the extreme accessibility it gives to the crankhead and main bearings, while a cylinder is rapidly replaced should occasion arise. Accessibility and facility of overhaul are, of course, of the utmost importance for marine work.

The cover, it will be seen, is a simple steel casting, the inlet and exhaust valve boxes being separate from it. These boxes seat upon coned joints in the cover, a ground metal to metal joint preventing leakage from the compression space. They are very thoroughly water-cooled, as will be seen in the elevation, the inlet valve-box even having a recess turned on its exterior into which water from the cover has access.

The water joints between the top of the cover and the valve boxes are made by indiarubber rings compressed below the flange of the latter. While no trouble is experienced on service, yet in later engines Messrs. Vickers make this joint by a pair of rubber rings in grooves on the periphery of the box, which enter into a slight recess in the cover. The advantage of this is that the joint becomes a sliding one, automatically compensating for any wear due to grinding down of the valve-box. A similar water joint is fitted between the bottom of the liner and the jacket, the two grooves being visible in the illustrations.

The exhaust and induction valves are of nickel steel, the former being water-cooled by flexible indiarubber armoured hose connected to the valve head. The inlet water passes down a central tube to the bottom of the exhaust valve and escapes upwards around this tube. The practice of water-cooling exhaust valves is followed by Messrs. Vickers even in their smallest submarine engines, one advantage being that the spindle clearances may be kept fine so that on starting the leakage of gas into the boat will be negligible compared with that from uncooled valve spindles in which a comparatively large clearance has to be allowed for expansion due to heat.

The separate valve-spindle guides will be seen in the section in Fig. 2, taken at the No. 11 cylinder, this being in accordance with the desire for extreme durability of all parts. Lubrication is not now fitted to the valve spindles. The head gear calls for no particular comment beyond stating that the spring spindle has a tee-end at its lower extremity, so that if it is depressed and then turned through a right angle about its axis it can be readily removed with its spring.

The cylinder proper is very elementary in form and consists of a plain cast-iron liner surrounded by a corrugated sheet steel jacket. This latter terminates at its lower end in a pressed forging, to which it is welded, and at the top a flange is welded to the jacket and is jointed to the underside of the sandwich plate. The liner has a number of steel bosses riveted through it, as indicated in the elevation of the eight-cylinder engine (Fig. 3). These bosses are machined to form stuffing boxes through which the piston lubrication connections pass; these connections being screwed into the liner. Eight of these feeds are fitted to each cylinder, and are supplied by a sight-feed force lubricating pump. In practice this pump is set to a low output, as very little lubrication is required for the piston.

The piston is of simple design in cast-iron. The top is concave and fitted at the centre with a screwed hole for a lifting bolt. This hole at one time held a special plug designed to maintain a high temperature, and thus to facilitate combustion, but this was found unnecessary and is not now fitted. Though the hole is left open to the flame no harm is occasioned thereby, the main impact of the injection not coming upon the centre of the piston as in an air-injection engine. There are six piston rings, 0·375 in. wide at the upper part of the piston, and one wiper ring at the bottom. The gudgeon pin is pressed hollow from special case-hardening steel, a plug being subsequently fitted to exclude the oil. The diameter is in three steps, as is usual, and is tightly driven into the piston, being secured at one end by a set pin and at the other by a key. A light aluminium guard is fitted over the top of the connecting rod and is secured by the gudgeon-pin set screw and by a special stud at the opposite side. The somewhat complicated lower guard originally fitted has been abandoned.

The connecting rod is of plain turned design. The top end is spherical with a non-adjustable gudgeon bearing, consisting of a bronze bush pressed into the eye of the rod and lined with white metal. This bush has a radial hole through it at the middle of its length, this hole communicating with a groove turned in the eye of the rod. By this means, if the bush should by accident or carelessness turn slightly, the oil supply from the hollow rod is not interrupted. The lower end of the rod is forged into a palm in which the crank-head brass is spigoted, provision being made for a compression plate. The crank-head brasses are of bronze, white-metal lined with a circumferential non-staggered oil groove at their middle length. The lubrication oil passes into the top of the main bearings, thence through the crankshaft to the crank-pin, from thence up the rod to the top end. It will be noticed that this design of crank-head is somewhat heavy, and Messrs. Vickers have adopted a modified design in cast steel for crank-heads of their non-Admiralty work.

The crankshaft in the twelve-cylinder engine is in four three-throw sections, and was maintained at the same diameter as the solid shaft in standard six, eight and ten-cylinder engines, namely, $7\frac{1}{2}$ in. Nickel-chrome with hollow journals and pins was originally fitted throughout the large engine, mainly to save weight and to gain experience of this material in such shafts, the maximum stress not being materially affected by the addition of the extra cylinders. Difficulties in supply during the war led to this being, in a number of twelve-cylinder engines, used only for the aft two lengths, the solid carbon steel pattern as originally used in the smaller engines being used for the forward lengths. All these shafts are oil-toughened, and the pins are trued by hand and lapped after turning.

The exhaust main is not shown on the drawings, but it consists of a pair of water-jacketed headers, one for each six cylinders, built up in lengths with independent outlets to atmosphere. The Admiralty engines are fitted with cast-iron mains, but for ordinary purposes welded sheet steel has proved quite satisfactory. The order of firing of cylinders is 1, 7, 3, 9, 2, 8, 6, 12, 4, 10, 5, 11, and deflecting diaphragms are fitted in the mains to prevent interference between the cylinder exhausts.

The flywheel is of cast-iron fitted with teeth on the outside to engage with a 3-h.p. electric or hand-turning gear of Vickers' patent, specially designed for instant operation, and to meet the limited space available. The centre eye of the wheel is separate from the rim to which it is bolted by a series of bolts shown in Fig. 3, and it is divided along its diameter to facilitate machinery overhaul in the boat.

The twelve-cylinder engine illustrated is of the latest class, in which the unit system of fuel pumps originally favoured by the submarine service is fitted. In this the inlet and exhaust valve cams are fitted on a shaft running in ring-oiled bearings, at about the middle height of the engine. The lower end of each of the long push rods carries the case-hardened steel roller, and on either side of it is a guide block sliding upon specially prepared guides in the cam casing. A loosely fitting cover surrounds the push rod, and excludes dirt from the casing. A lead from the bearing oil supply is led to each cam roller and guide, the oil entering at the back and squirting into the hollow interior of the roller block, as shown in Fig. 2. The cam casings drain back to the crank-case, the only oil remaining in them being that in the small troughs under each cam into which the latter dip. The cams are wide, and are made of case-hardening steel pressed to a hollow section. The cam-cases—which were originally of aluminium alloy, but owing to other demands for that material have during recent years been made in cast-iron—are bolted to the camshaft brackets, and are provided with a footstep to facilitate access to the top gear. The lower camshaft is driven by spur gearing in the middle bay of the engine, while the upper camshaft receives its motion through a bevel-driven vertical shaft visible in the middle of Fig. 1. The timing gear on the vertical shaft is also shown on this illustration. On rotating the horizontal wheel it is moved vertically upon the thread shown, and thereby advances or retards the upper shaft relative

to the crankshaft owing to the upper bevel wheel being driven through a number of spiral keys on a coupling moved vertically by the hand wheel and sliding on straight keys on the vertical shaft. As the upper shaft carries the fuel admission cams, this effect is analogous to that of moving the "spark" in a petrol engine. It is a refinement not usually applied to Diesel engines, but intelligently used it enables the best setting for any condition of working to be obtained.

For ordinary running the spray valve, when at full power, is due to be opened at about 16 deg., measured on the crankshaft, before the top dead centre of its piston, and the controls, which will be presently described, have been re-designed so that as the duration of the spray valve opening is reduced for lower powers; the point of injection is simultaneously adjusted to that suitable for ordinary surface conditions. With these conditions it is unnecessary to adjust the timing gear when varying the power, but in the event of a heavy "charge" being put upon the main motors of the boat, thus considerably increasing the load on the engine, it is possible to retard the injection a few degrees or with a light condition of the boat or a following wind the timing may be advanced slightly. Adjustments of fuel valve settings to suit variations of fuel are also very conveniently carried out in similar manner.

Messrs. Vickers have carried out extensive trials in various conditions to investigate the effect of the timing gear and the result is to show that within the limits of practical working the brake horse-power and maximum cylinder pressure are both increased by advancing the injection, the curve of increase on a base representing the angle of injection being a straight line. Indicator cards varying in character from the flat-topped card representative of the normal air injection engine to the sharply peaked card of the explosion engine, can be obtained at will, and the whole forms a most interesting study. In ordinary trials the firm limits the maximum pressure to a more reasonable figure, but on occasions on service where extra speed has been required the engines have been run with timing gear adjusted to give cylinder pressures of 700 lb. per square inch and over without any ill-effect. The control of the spray valves is effected by the left hand vertical hand wheel seen in Fig. 1. This, by gearing, partially rotates the spray valve control shaft, the lowest of the three shafts running along the top of the engine. At each cylinder this shaft has a notched lever keyed to it. Alongside this lever is a similar lever with a spring clutch handle, the second lever being fixed to a short sleeve riding on the spray valve control shaft. When this sleeve is rotated by the handle the eccentric fulcrum mounting of the spray valve lever is partially turned by means of the two levers and the connecting rod, plainly seen in Fig. 2. The eccentricity of this mounting and the link proportions are so designed that a close approximation to the required point of fuel admission to suit any reduced duration of admission is obtained. Ordinarily the clutch handles are pushed forward to engage with the levers on the control shaft, in which case all spray valves are controlled by the hand wheel, and over a wide range of power a movement of this wheel is all that is required to regulate the power. Should it be desired to cut out any cylinder the handle is drawn down, disengaging the sleeve lever from the one alongside it, and on bringing the handle forward to a notch in the fixed quadrant, as shown dotted in Fig. 2, the spray valve is put out of operation, a small cam on the sleeve lifting the suction valve of the fuel pump and putting it also out of action as the spray valve ceases to operate.

The whole is particularly simple, though the repetition of the units for each cylinder gives a first impression of complication, but it is plain that experience was necessary to enable the required somewhat complicated co-relation of functions of timing and duration to be obtained by such an elementary form of apparatus.

The fuel pumps at each cylinder are eccentric operated and consist of bronze castings supported in a steel casting secured to the cylinder cover. This casting carries the upper camshaft bearing, on the cap of which is mounted a separate small bearing in which the top-most shaft slides. This shaft is actuated by the right-hand wheel in the centre of the engine, and by means of a downwardly-projecting stirrup slides a spiral scroll cam at each pump to the position required for the correct fuel output. This output is varied as the cam does not allow the suction valve of the pump to close till the desired point in the downward stroke of the latter. The high-pressure pump is marked on No. 12 cylinder in Fig. 1, and the spring returning the tappet for the suction valve can be detected in the drawing. The bore of the pump is $\frac{1}{2}$ in. and its stroke 1 in., special soft packing being used in the gland. Ordinary webbed cone-seated valves are usually fitted, but ball valves have been found equally efficient, and are now finding favour in the service. The whole of the bracket, pump and details have been redesigned in Vickers' later models with advantages as regards ease of manufacture, weight and efficiency, but in so doing, interchangeability has been maintained to a considerable degree of detail.

The fuel from the pump passes through the pipe shown on the right of it to a strainer, and thence into an accumulator tube shown vertically just to the left of the right-hand column on No. 12 cylinder. It then passes to the spray valve. The strainer at one time consisted of a plate with fine holes drilled in it, but the later type, which is much cheaper and affords greater filtering area, consists of a series of perforated discs, each with a shallow circular projection on one face close to the edge. This projecting annulus is knurled, and a number of these discs strung on a central bolt form a cartridge with circumferential rows of tiny triangular holes on its surface, through which the fuel passes to the centre and thence through the end plate to the outlet pipe. A vent valve is fitted to the spray valve body, this valve, for convenience, being fitted on the head of the pulsator, which casting also forms the strainer body. The pulsator is a slightly flattened steel tube, and its function is to receive the fuel charge from the pump, when this is supplying only its own cylinder, pending the opening of the spray valve. A pressure gauge is mounted on the discharge pipe so that the pumping plant for each cylinder is complete in itself, as originally specified. At the bottom of the pulsator a valve is now fitted, and through this valve each pulsator can be connected to a main, originally fitted for priming purposes. The common practice is now to run with the pulsators coupled to this main, in which case the pumps are, of course, not measuring the fuel to each cylinder, the spray valves performing this function. This is opposed to the ordinary idea, but consideration will show that the valve is more likely to be accurate than the pump. The system thus run becomes a pressure system, and all that is necessary is to maintain the required pressure and to adjust the spray valve functions to regulate the power. A development of this system will be seen when the eight cylinder reversing engine in Fig. 3 is described.

A safety valve is fitted to the pressure rail in the centre of the engine, as is also a quick opening valve for immediately stopping the engine in case of emergency by releasing the fuel pressure.

The spray valve in the standard engine is an ordinary spring-loaded conical valve, made in hard steel. The gland is packed with fuel-pump packing and, with reasonable care in first packing, is perfectly satisfactory. The valves can be individually adjusted by the nuts seen on the end of the spindle. The nozzle is of tool steel and its securing nut is bedded upon the coned seat in the cylinder cover so that there is no tendency for fuel to leak through joints to the cylinder. The number and disposition of the holes in the nozzle depend upon circumstances, but in the engine described they are five in number, and 0·0205 in. in diameter, the jets being at 68 deg. with the axis of the cylinder.

The lower part of the spray valve-box is a steel stamping, the upper part, which contains the spring and the guide plunger upon which it bears, is of cast steel, the eccentrically-bored fulcrum bearing of the spray-valve lever being mounted between the two parts. The spray valve is operated by a lever of the first order, shown in Fig. 2, which has a wide roller loosely mounted in a groove at its inboard end, this roller engaging with the fuel cam. The fuel cam consists of a small hardened toe-piece mounted in a steel cam disc on the upper camshaft and at the centre line of the cylinder, and is capable of slight circumferential adjustment on its disc. A sheet save-all is fitted under each pump, and by means of a drain pipe avoids waste of fuel when cleaning filters or venting the system.

The engine is started by opening a T-handled air master valve, situated near the centre of the engine, which admits air to the two starting air boxes between the end groups of cylinders. In these boxes are small partially-balanced valves, normally kept off their seats, and thereby free of the cams, by a light spring. When air is admitted the valves are blown down upon their seats and are operated in correct sequence by cams on a pair of athwartship shafts bevel driven from the lower camshafts. At one time air starting was regarded as an emergency measure, the electric motor being ordinarily used in submarines. Air starting valves fitted with hardened ends engaging with the cams were satisfactory in such circumstances. Nowadays air starting is recognised as safer in the event of water having entered the engine during driving, and the air-starting valves have been provided with hardened steel rollers to give increased durability, a very neat little design having been adopted. The air passes from the air-starting box to the individual cylinders, passing into the cylinders through a spring-loaded non-return valve on the cover. As seen in Fig. 2, it passes through small holes after leaving the non-return valve so that no broken part can enter the cylinder in case of breakage of a valve. The engine having started on air the spray valves are put in gear, and afterwards, when convenient, the air master valve is closed. With pipes and pumps fully primed, firing begins within the first two or three revolutions, the absence of the chilling effect of the injection air doubtless accounting for the ease in starting.

At the back of the engine is a bearing oil pump, of double-acting type, and a plunger pump for maintaining the gravity fuel tank full. These pumps run at half engine speed, and are driven by bevels from one of the starting air camshafts. In some boats where automatic compensation of fuel by sea water pressure is fitted, the gravity fuel pump is disconnected. A tendency is growing to accept separately-driven pumps in submarines, and if this matures the arrangement of any engine will be greatly simplified, the necessity of finding an accessible site on the engine for the auxiliaries presenting considerable difficulties where space is a primary consideration. The indicator shafts are also driven from the air camshafts. These consist of a shaft for each set of six cylinders, driven at engine speed, upon which are mounted adjustable eccentrics whose straps and rods move a vertical plunger at each cylinder to which the wire actuating the indicator is attached. A clutch with special tooth causes the indicator shafts to revolve when cards are to be taken. By this method the crank pits are kept clear of all parts likely to fail on long runs. A pair of small lubricators of plunger type are also fitted at the back of the engine. These supply oil to the pistons as previously described.

The induction header is not shown on the drawings, but it consists of a light steel pipe for each half of the engine, to which the induction valve boxes are coupled by trumpet-shaped pipes. The air to each header passes from the atmosphere through a bell-mouthed inlet, while a lead is also arranged to take a small air supply from the crank-case. This latter supply leaves the crank-case through a hole in each tie-plate and passes through a light fibre non-return valve on its way to the induction header. By this means the crank-case, which has small inlet grids at the ends of the engine and in the centre, is maintained under a slight vacuum, and the atmosphere in the engine-room is not contaminated by the egress of vapour when running or after stopping.

The circulating water is led from an independent rotary pump to a main supplying the jackets, from which it passes to the cover through six tubes through the sandwich plate, the joint round these tubes being made by vulcanised rubber rings. It then passes to the jacket of the exhaust bend and away. The exhaust valves are fed from a separate main with a filter at either end. A short-circuiting valve is fitted between the pump suction and the cooling water discharge, so that in the event of a sudden dive to a great depth being made, the sea valves may be closed, and yet a circulation of the water in the closed system can be maintained till the engines have cooled.

The fuel oil flows from the gravity tank, which is placed in any convenient place in the engine-room, to the centre of the engine, passing first through a settling pot where sediment and water can be removed, and then to the middle of a main running the length of the engine. This connection is so arranged that surging from end to end in a seaway is prevented, and from it the main rises towards each end facilitating venting and enabling a standard main to be used whether the rake of the engine in the boat is up or down. From this main small pipes with shut-off cocks lead to each high-pressure fuel pump, the fuel being filtered by a fine gauze filter embodied in the suction chamber of the pump. The pump itself, with its discharge filter, has been described above.

Examination of the drawings will show that all of the parts of the engine are particularly accessible, while in the construction ease of overhaul and adjustment has been carefully studied. To this and to the moderate rating of 1,200 brake horse-power to 1,400 brake horse-power, at 380 r.p.m. to 400 r.p.m., may be attributed the long and successful running that so many of the British boats have carried out without the necessity of assistance.

We are able to give, in Fig. 5 on page 10, a copy of a typical indicator diagram from one of these engines, together with the record of a 6-hours' full power trial (Table No. I) independently recorded, which will doubtless be of interest in view of the many discussions regarding the efficiency of solid injection.

Fig. 3 shows an eight-cylinder reversing engine in elevation, Fig. 4 giving an end view. A number of these engines were ordered by the Russian Government from Messrs. Vickers for patrol vessels. The cylinder dimensions are the same as in the twelve-cylinder engine, namely 14½ in. diameter by 15 in. stroke, the engine easily developing 800 brake horse-power at 380 r.p.m. It will be noticed that the construction of the larger engine has been closely followed whenever possible, but in this instance the engine has been designed to operate on the common fuel pump or "rail" system. The fuel pumps are shown in the end view and are driven by spiral wheels from the

TABLE I.—SIX HOURS' OFFICIAL SHOP TRIAL OF SUBMARINE ENGINE 1,200 B.H.P. DATED SEPTEMBER 5, 1918.

Time.	R.P.M.	B.H.P.	Fuel Used.		Fuel Pressure.	Controls at		Circulating Water.	Lubricating Oil.			Atmosphere Temperature.
									Pressure.	Temperature, Fahrenheit.		
			Lb. per Hour.	Lb. per B.H.P.-Hr.		Fuel Pump.	Spray Valves.	Pressure.		In.	Out.	
					lb. per sq. in.			lb. per sq. in.	lb. per sq. in.	deg.	deg.	deg.
1st hour	379·8	1,209·0	461	0·381	4,500	9	18·5	10	12	68	87	60
2nd hour	382·5	1,218·5	461	0·379	4,500	9	18·5	10	12	71	101	62
3rd hour	381·0	1,213·9	461	0·380	4,500	9	18·5	8	10	72	106	64
4th hour	381·8	1,216·3	457	0·376	4,500	9	18·5	8	8	87	109	62
5th hour	381·4	1,215·0	479	0·394	4,500	9	18·5	10	12	98	116	63
6th hour	381·7	1,216·0	461	0·380	4,500	9	18·5	10	12	104	114	63
Average	381·3	1,215·0	463	0·381	—	—	—	—	—	—	—	—

Indicated horse-power, 1520.
Inspecting Officer's Report: "The engine ran steadily and well, and no trouble of any sort was experienced throughout the trial. The crank pits remained clear of gases, and the exhaust was light and good. The trial is considered satisfactory."

TABLE II.—*Engine No.* 521 *Port. Official Starting and Reversing Trial, April* 26, 1919.

From.	To.	Condition of Engine.	Volume of Compressed Air in Use.	Air Pressure.			Time to Start.	Revolutions to Start.
				Before.	After.	Difference.		
			c. ft.	lb.	lb.	lb.	sec.	
Stop	Ahead	Cold	36·4	550	525	25	5	8·0
Stop	Ahead	Cold	36·4	525	510	15	3	4·0
Stop	Ahead	Cold	36·4	510	495	15	3	4·0
Stop	Ahead	Cold	36·4	495	485	10	3	4·0
Stop	Astern	Cold	36·4	480	465	15	2	3·0
Stop	Astern	Cold	36·4	465	450	15	2	2·5
Stop	Astern	Cold	36·4	450	440	10	2	2·5
Stop	Astern	Cold	36·4	440	425	15	2	2·5
Astern	Ahead	Slightly Warm.	36·4	400	380	20	15	—
Ahead	Astern	Slightly Warm.	36·4	380	365	15	16	—
Astern	Ahead	Slightly Warm.	36·4	365	355	10	16	—
Ahead	Astern	Slightly Warm.	36·4	355	345	10	15	—

Note.—Load condition as at full power.
The fuel system was primed by hand for the first start to approximately 400 lb. pressure. This was not necessary for the subsequent starts, as there was sufficient residual pressure in the system. For reversing no hand priming was carried out.
Of the time taken to reverse the engine, from 13 seconds to 14 seconds were absorbed in hand manipulation of shutting off and opening the controls and actuating the reversing wheel. Number of turns of reversing wheel from full ahead to full astern equals 23.

TABLE III.—*Engine No.* 518 *Port. July* 3, 1918. *Air Starting Trial Arranged for Lloyds Surveyor.*

Thirty-four starts were made, dropping the pressure from 450 lb. to 195 lb. per square inch. Volume of compressed air in use 37·5 cub. ft.
The engine was cold, not having been touched since the previous morning's preliminary air starting trial.
Load condition of engine as at full power.
Note.—The number of starts could have been increased, but the air bottles were some considerable distance from the engine, and due to the long length of pipe, considerable "wire drawing" took place.

end of the crankshaft. There are four plungers, 0·66 in. diameter by 1·25 in. stroke, the revolutions being 190 at full engine speed. Each pair of pumps can be isolated from the other or put out of action if required. A separate discharge is led to the control box in the centre of the engine, so that if required one pair of pumps may serve one group of four cylinders. By these means, total stoppage in the event of failure of either pump or fuel main is prevented. As a matter of fact, these pumps, with their double suction valves and forced lubrication are wonderfully reliable, while failure of fuel piping is almost unknown, the high pressure of sometimes over 4,000 lb. per square inch presenting no more difficulty than lower pressure in thinner piping.

The smaller hand wheel is free to be rotated when the reversing gear is in the full ahead or astern position. Its first turn opens a master valve in the control box which passes air to the air distributor boxes at the ends of the engine. These are similar in principle to those on the twelve-cylinder engine, but are disposed radially in a neat bronze casting, one cam only in the box being required for each direction of running. Further turns admit fuel to the main supplying first one group of four cylinders and then the remainder, the air being finally shut off. A last turn stops the engine by shutting fuel off the mains. The fuel passes through a strainer and a shut-off valve to the spray valve. Quick-closing shut-off valves are fitted in later engines of this type, the handle by its position serving as an indicator as to whether the supply is open to the spray valve. A small lever which may be seen at the running position is connected to the fuel pump, and by modifying the operation of the mechanically-operated suction valves in the usual manner, regulates the pressure of the fuel supply, and thence at any setting of the spray valve determines the amount injected.

The spray valve regulation is effected by the lever at the top of the engine in the middle. This lever rotates a shaft passing through bearings on each cover, the intermediate fuel levers being mounted on eccentrics, on this shaft. This intermediate lever is moved through the intermediary of a short tappet rod by the fuel cam on the single camshaft, which in this instance is mounted on brackets attached to the top of the columns and carries the inlet and exhaust cams also. The other end of this intermediate fuel lever depresses the bell crank of the spray valve, a roller in the lever sliding upon a hardened piece in the bell crank. The spray valve in these engines differs from that of the twelve-cylinder engine, the spindle being totally enclosed within a steel stamping and operated by a bell

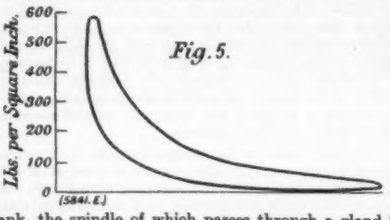


Fig. 5.

crank, the spindle of which passes through a gland in the side of the valve casing, a ball race taking the unbalanced fuel pressure on the bell crank. This design was chosen as lending itself better to the upper camshaft arrangement than did the standard valve.

The reversing of the engine is carried out by the large hand wheel, which, through a scroll and crank, first by partially turning a reversing shaft—mounted in the same bracket as the camshaft, but above it—swings the inlet and exhaust push rods clear of their cams and then, after sliding the camshaft till the reverse cam is in the correct position, replaces the push rods in their working position. This hand wheel is back-locked with the starting wheel so that it cannot be operated except when the latter is in the "stop" position. The fuel and air-starting cams being of small lift can be pushed past their respective rollers without the latter being otherwise lifted, the cams and rollers being tapered to facilitate this operation.

The drive for the camshaft in this engine is entirely by spur wheels, the sliding motion of the camshaft wheel being met by the provision of a wide wheel in the train. The bearing oil and gravity fuel pumps, together with the usual indicator gear and piston oil pumps, are at the back of the engine in the centre bay. The two former pumps can be disconnected from the engine and worked by hand for priming purposes, a similar arrangement being followed in the twelve-cylinder engine.

Hand reversing was adopted instead of power gear on the ground of reliability after long service. Tables II and III, annexed, give the results of the starting and reversing tests, and incidentally show the rapidity of starting and the low consumption of air.

These engines gave great satisfaction to the Russians, but owing to the collapse of that country they did not receive them. A number were allocated to the Anglo-Saxon Petroleum Company, who used them for installation in some converted sailing ships. For this purpose, to suit the low speed of the ship, the propellers were designed to absorb 630 brake horse-power at 320 r.p.m., the engines being adjusted to suit. A number of these installations have been carried out, some in China, with satisfactory results.

These engines are interesting as showing a complete remodelling of type while maintaining interchangeability of important parts to a considerable extent. Attention to details in the re-design enabled the weight of the reversing design to be brought below that of the eight-cylinder non-reversing design on which it was based, a few inches increase in overall length over the latter design having had to be taken to accommodate the reversing gear and central drive in the same bay.

The success of this design led to a demand for a twelve-cylinder non-reversing engine on similar lines, and a perspective view of this type is given on page 16. Comparison with the designs previously described will show that as little alteration as possible in standard parts has been carried out. The high-pressure fuel pump is driven by the crank-shaft and supplies fuel to a main from which the spray valves are fed. The fuel pressure is controlled at will by a lever in the centre of the engine, while a lever higher up controls the spray valves. This undoubtedly represents the simplest form of injection ever applied to a high duty heavy oil engine.

DOUBLE PAYMENT OF INCOME-TAXES.—In view of the exceptional hardship resulting to British firms and individuals residing in France from the existing regulations in respect to income-tax, the British Chamber of Commerce, Paris, has made representations to the Royal Commission now sitting to consider this and similar matters, and proposes to send a delegate to London to submit concrete cases to the Commission. The Chamber will therefore be pleased to receive from members in France who are affected by the British income-tax laws, concise and specific details of revenue on which they are compelled at present to pay not only the French income-tax, but the British income-tax on the same items of income.

THE LATE SIR JOHN BRUNNER, BART., P.C.—Sir John Brunner, the eminent chemical manufacturer, who died of heart failure at Chertsey on July 1, was born in the same year (1842) as Lord Rayleigh, who predeceased him by one day. He came from an old Swiss family which had been settled near Zürich for four centuries. His father, a Unitarian clergyman, came over to England and married there, and John Tomlinson Brunner was born at Liverpool. Having entered a Liverpool shipping office when 15 years old, he was in his twentieth year manager of the chemical works of Messrs. Hutchinson and Earle at Widnes, where he met Dr. Ludwig Mond. The two became friends, bought, in 1873, the Winnington Hall Estate, near Northwich, and made alkali by the Solvay process. The new firm soon extended to Sandbach and Middlewich, and under the style of Brunner, Mond and Co. expanded into one of the biggest and most successful works in existence. Leaving the scientific side to his partner, Brunner took the charge of the general management and remained chairman of the company till his end. A man of wide interests and a generous heart, he was an enthusiastic trade unionist though a capitalist, and a promoter of peace and liberalism in politics and religion, of liberal education, inland navigation, and of archæological research. With a short break he represented Northwich in Parliament as an advanced liberal from 1885 till 1909, when he retired. The juniors at the works were given a scientific training, and he did much for benevolent institutions. One of his gifts to the Corporation of Widnes was the Widnes-Runcorn suspension bridge, which cost him 68,000*l.* it is said. He was created a baronet in 1895 and sworn of the Privy Council in 1906; his honorary degree as LL.D. came from Liverpool. His eldest son, Mr. John Fowler Leece Brunner, who succeeds to the title, is also a director of the firm.

LEAD-SODIUM ALLOYS.—It has long been known that an addition of sodium to lead hardens the lead. As nearly the same effect can be obtained by the addition of other elements, however, which do not render the lead subject to corrosion as the sodium is apt to do, the lead-sodium alloys have little been studied. In the *Zeitschrift des Vereines Deutscher Ingenieure*, of May 10 last, Dr. J. Goebel describes some tests to which he submitted ternary alloys of lead-sodium-mercury and lead-sodium-tin. He started from the binary alloys Pb-Na, Pb-Hg, Pb, Sn, fusing the constituents in a hydrogen atmosphere, and cast test cylinders, 2 cm. diameter, 1·75 cm. high, which he submitted to hardness tests (Brinell), bending tests and impact tests, the latter by repeatedly dropping a tup of 5 kg. on the specimen. The specimens were tested immediately after quenching, or eight days or more later. Lead dissolves 0·8 per cent. of sodium, and the mixed crystals formed in the 4 per cent. alloy contain the compound Na_2Pb_5, the eutectic contains 2·5 per cent. of sodium. The addition of up to 7 per cent. of mercury to lead raises the hardness figure from 4 to 9. When sodium (up to 4 per cent.) is added to the lead, the hardness increases very much, reaching the value 8 when the Na percentage exceeds 0·8, keeping nearly at that value up to 2·5 per cent. and falling off with higher Na percentages. The hardness figure of zinc would, by the same test, be 27, that of electrolytic iron 47. The further addition of mercury to these binary alloys does not make much difference; the curves are in general more regular, however, and the maximum is shifted nearer 2·5 per cent. Na. Ternary alloys containing less than 1 per cent. of Na are softer than the corresponding Pb-Na alloys. The bending tests gave better values when mercury was added to the lead, and poorer values when sodium was added. The crushing tests showed that the reduction in height of the cylinder was much decreased by the addition of sodium, and the formation of cracks was also less noticeable; but hardness and crushing strength did not go together, and two specimens of equal hardness might give very different crushing values. The experiments with the binary and ternary tin alloys, Pb-Na-Sn, were not satisfactory; the sodium made the alloys (up to 7 per cent. of tin) harder, but not stronger, and the conclusion drawn is that only the lead sodium-mercury alloys might answer for certain technical purposes.

INDUSTRIAL NOTES.

A MEETING of the General Council and members of the National Alliance of Employers and Employed is being held to-day at the Caxton Hall, Westminster, when addresses will be given by the Right Hon. Arthur Henderson and other members of the National Industrial Council, and a discussion will take place on the effect upon the work of the Alliance of the establishment of an Advisory Council of Employers and Employed as recommended by the Committee of the National Industrial Council.

In the evening, Lord and Lady Brassey are entertaining the members of the National Alliance to an evening party, at 24, Park Lane, W.

The National Alliance has now established 30 Joint Committees of Employers and Employed in various provincial centres. The latest committee is one for the County of Oxfordshire, on which employers and employed in agriculture and kindred industries are represented.

Under the National Insurance Acts as they stand at present all manual workers are required to be insured without regard to their rate of remuneration, but persons employed otherwise than by way of manual labour are not insurable as employed contributors if their rate of remuneration exceeds 160*l.* a year. The present limit of 160*l.* a year was fixed in 1911, and, owing to the general increase in salaries and wages, it does not now represent the same dividing line between non-manual workers included in, and excluded from, insurance. A Bill presented by Major Astor, supported by Dr. Addison, Mr. Munro and Mr. Macpherson proposes the substitution of 250*l.* for the previous limit as affording the closest possible approximation to the extent to which wages have risen in the case of the classes of non-manual workers affected.

An article in *The Yorkshire Post*, on the projected ironstone developments on the Hambletons, states that in considering the possibility of working thinner seams away from the present recognised ironstone area, it may be well to point out that Bilbao ore, for example, is costing more for labour in Spain, and the freights which, in pre-war time, were about 4*s.* 4*d.* per ton, Bilbao to the Tees, are now up to 30*s.* per ton. Competing with such high prices enables a mine-owner in this country to work a considerable quantity of previously unsaleable material along with the proper article, and still be able to sell at a profit. Many factors determine what it may be possible to use, and the adoption of improved methods of manufacture, the freight market, and the easy access to sources of fuel supply have an important bearing. The necessity of a greatly increased output from the furnaces during the war led to an enormous importation to the Tees of home ore from Northamptonshire and from the Lincolnshire deposits. The arrangements with the Ministry of Munitions have made this possible from the financial point of view, and the supply of home ore to the Middlesbrough furnaces from these sources still continues. How long it can be maintained profitably when the industry returns to a normal basis, plus the higher wages, will require careful consideration.

The available quantity of ironstone in the main Cleveland seam is roughly 608,000,000 tons, of which 270,000,000 tons had been worked by 1913. This leaves 338,000,000 tons, which is calculated to last fifty-six years at the former rate of working of 6,000,000 tons per year. The war years, however, have seen that rate considerably increased. Even when regard is had to the fact that the top seam, the Pecton seam, and the 2 ft. seam have not been worked, and that these probably contain more ore than the main seam, the exhaustion of the supply may be expressed in terms of comparatively few years. If the cost of working can be reduced to a remunerative figure, ore from these seams will probably compete with imported ores, whether from foreign sources or from the home fields remote from Teeside. The necessity of fresh sources of supply within reasonable distance of the blast furnaces is impressing the Cleveland ironmasters, and on the experience at Kirby Knowle, when developments have reached a sufficiently useful stage, will probably depend an extension of the ironstone mining to the western confines of the Hambletons. Having regard to the fact that the Cargo Fleet Company, who were the last to commence blast furnace work in the area, erected calcining bins at their Liverton mines, to reduce the haulage of crude ore, it is probable that future developments will follow this lead. It means a reduction of 30 per cent. in carriage, the calcined ore representing only 70 per cent. of the raw material—an important factor in transport.

We have received a copy of the final report of the Joint Committee of Employers and Employed appointed at Lord Balfour of Burleigh's Conference, held on February 9. It is published by the North London Manufacturers' Association, 18, Finsbury-square, E.C. 2. We dealt in our issue for April 11, on page 468, with the interim report, which was presented to Lord Balfour of Burleigh on April 3, and widely circulated; this is reproduced in the final report in question as Appendix B. Following upon the presentation of this interim report, the Joint Committee proceeded to deal with what they had agreed to be six main causes of industrial unrest, namely: Suspicion; fear of unemployment; unfair division of profits and products; status in industry; extremist propaganda; and economic fallacies. These six main causes are reviewed in detail in an appendix, Appendix C, to the said final report; the signatories add that they consider the surest remedy for Industrial unrest to be in the cultivation of greater communicativeness between, and more spontaneous goodwill on the part of both employers and employed in the discharge of their relative duties. Causes of dissatisfaction and grievances are discussed in detail, and a number of recommendations are given, together with abstracts of the speeches made at the Conference.

The Council of the North London Manufacturers' Association, who are responsible for convening the Conference at which the Joint Committee in question was appointed, announce that a further conference to which the final report is to be submitted is to be held on the 23rd inst. In the meantime, the report will repay careful reading.

In our last issue we referred to the strike and settlement in the cotton trade. Against all expectation the mills did not open for the resumption of work last Monday, further difficulty having arisen owing to the refusal of the members of the Operative Spinners' Amalgamation to abide by the terms decided upon. Their action is contrary to the decision of the Legislative Council of the United Textile Factory Workers' Association. The latter association has asked that a meeting take place to discuss the grievance, a request which the employers have agreed to. It is stated that the rejection by the spinners of the terms arrived at and referred to in our last issue is due to the action of the shop stewards in the spinning mills. The spinners object to the clause which states that the altered hours of work and rates of pay are to remain in operation without change for eighteen months, after the expiration of which period one month's notice is to be given by either side of any desired alteration; they object to the period being limited to eighteen months only.

The annual general meeting of Messrs. Brunner, Mond and Co., Limited, was held in Liverpool on June 20, when Mr. Roscoe Brunner gave information on his company and on chemical products in general. In regard to the trade of the United Kingdom, he said there were signs that the corner may have been turned, but he thought the revival of trade would have come much earlier had the world been convinced that there was some finality to the demands of labour. He did not think any sane man would grudge to labour its fair share of the profits of trade, but unless labour realised that there cannot be profits without proper production and that decreased production led to lesser profits and lessened employment, there would be no revival of trade. Coal had more than doubled in cost during the war, and the production had gone down to such a point that our export trade, upon which the prosperity of the country so largely depended, had practically disappeared, and we were warned by the Coal Controller that not only will our houses be rationed as they were last winter, but that he may have to cut down the supplies of fuel to industry, which again will lead to further unemployment. We were told that the cure for all this was to nationalise the coal mines. He failed to find that the State had done anything whatever better than it was done by private individuals. During the war the Government factories may have produced on as favourable terms as the private works, though he could assure the meeting there was considerable controversy on that point; but as Sir Keith Price stated the other day, and he was the head of the Department of the Ministry of Munitions which had charge of His Majesty's factories—while their costs were as favourable as the costs of private employers the State had had the benefit during the war of the advice and help of many of the most eminent engineers and chemists and business men, and that in peace times the State would not have had the advantage of those gentlemen's services. Many of those services were, of course, given free, therefore the factories were not burdened with such costs. The State would not now get the benefit of the services of those eminent gentlemen, and to suppose that the ordinary civil servant—and when a man went into the Civil Service he very quickly became ordinary as a rule—was going to put into the coal trade the enterprise of a private owner was to expect too much, nor was it likely that the State would risk the capital the private owner had put into the mines during the past centuries.

Loading and unloading in the Liverpool docks had been so delayed that a smaller amount of foodstuffs will enter the country than should have entered. The dock labourer was going to be short of coal next winter, and if the delay in the import of foodstuffs went on the miner would be short of food. So each trade reacts upon another, and all react upon the prosperity of the country. In regard to coal control during the war, he added, the Coal Controller estimated that he would save 700,000,000 ton-miles per annum by taking the whole of the distribution of coal into his own hands. He had not, so far as he (the speaker) was aware, published the result, but in the company's case it was calculated that his intervention has led, not to any saving, but to a loss of more than 2,000,000 tons-miles per annum.

In the course of the statements he made at the annual meeting of Petters, Limited, Yeovil, held on Thursday, June 19, Mr. E. W. Petter, the managing director, said that no portion of the Yeovil works had been sold to Messrs. Vickers, Limited, neither had the company been in any sense absorbed by Messrs. Vickers. The scheme was a joint enterprise on the part of Messrs. Vickers and the company to occupy the works at Ipswich built by the Consolidated Diesel Company, for the manufacture of the larger sizes of the Petter oil engines. They were laying themselves out to manufacture their oil engines by methods of mass production, and they meant to turn them out in such quantities and with such accuracy and skill that their competitors at home and abroad could not hope to challenge the Petter engine. On the other hand, they had made a close study of the world's markets, and they would have an organisation for selling their engines which would challenge comparison with the finest organisation of any of their competitors at home or abroad.

THE EMPIRE MUNICIPAL DIRECTORY.—The 1919–20 edition of this directory makes its thirty-seventh annual appearance rather later than usual this year, doubtless owing to difficulties of compilation arising out of war conditions. About one-half of the book is occupied, as usual, with a directory of local authorities, and their chief officials, for all parts of the British Isles and also for the British Overseas Dominions. This is followed by sections relating to road-making, engineering and building construction, cement and concrete work, ventilation, lighting and heating, water supply, sewage disposal, fire prevention, town planning, and many other matters of municipal interest, each section being a synopsis of recent practice and progress made in that particular branch of municipal work. Another useful feature included is a directory of institutions, associations and societies concerned with municipal and public health work, and the municipal engineering and sanitary trades directory will doubtless be welcomed by many users. The directory concludes with a diary giving three days to a page, and this feature helps to enhance the value of the work as a desk companion for municipal officials. The price of the volume is 5*s.* net, or post free 5*s.* 6*d.* in the United Kingdom, and 6*s.* abroad. It is published by the Sanitary Publishing Company, Limited, of 8, Bream's Buildings, London, E.C. 4.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—A conversazione was held by this Institution on June 25, at the Natural History Museum, South Kensington, to meet the members who had served in H.M. Forces during the war. In the course of his speech of welcome, the president, Mr. C. H. Wordingham, C.B.E., said it was no hypocrisy to state that we had not won the war in our own strength. Although we were fully warned we were utterly unprepared. We had but a handful as armies, a navy which we are assured on the highest authority was deficient in certain vital respects, we had practically no hospital ships or ambulance trains, no adequate supply of suitable armament, and we were matched against a nation which had spent forty years in steady preparation, which had sucked the brains of every other nation for ideas and inventions, which stopped at no degradation in the practice of war, using the foulest methods of the vitriol thrower and murderer, and yet we won. We may say it was due to this man or that, to the sailor or the engineer, to our money or to our cleverness, but if we are honest we shall say that we owe it to God's goodness and mercy. It was true that many of those who stayed at home had been just as indispensable as those who had fought, and they had done their utmost to contribute to the result of the nation's effort, but after all nothing can come up to the services of those in the field. They had worked as hard as any, for longer hours than most, and over and above all they had faced the foe at close quarters. It was no ordinary foe, but a foe without a spark of honour, chivalry, or human feeling, a foe full of bluster when victorious with overwhelming odds on his side, and a craven and snivelling coward when beaten. A foe with whom though he sign a treaty of peace we must ever be alert to watch lest at the last he sting us like an adder. "We as engineers," added Mr. Wordingham, "are specially proud of our men, because while a large proportion entered the ranks, the greater number subsequently earned commissions. We are proud of their merit, but especially proud because the facts show that an engineer's training fits him for administrative work and the command of men."

THE ROYAL AGRICULTURAL SOCIETY'S SHOW AT CARDIFF.

(*Concluded from page* 837 *of vol.* cvii.)

IN our article of last week we referred to the fact that the most noteworthy feature of the machinery display at Cardiff lay in the large number of different types of the smaller class of agricultural tractor which were staged. We then described and illustrated the examples shown by Martin's Cultivator Company and Messrs. Clayton and Shuttleworth, and now propose how to deal with some of the remainder. An inspection of the very varied types of appliance which were exhibited at this one show illustrates how far the farm tractor yet is from settling down to a fairly definite type, in the sense in which the commercial motor wagon has settled down to a definite type. It is possible, of course, that such confluence of type as the motor wagon has seen will never take place with the agricultural tractor since farm conditions in various parts of the country differ so much more widely than road conditions, and the clays of Essex will never be the chalks of Hampshire. None the less, it is hardly possible that the whole of the types now in being will survive in their present forms, and one may expect an ultimate movement towards a few more definite classes. We doubt if it is possible for the shrewdest judges yet to say what those forms will be. The conditions of operation are so onerous and various that only many years in the school of experience can ultimately weed out the unsuitable and direct the suitable along the correct path of development.

As things stand at present one may divide existing tractors—of which the Cardiff Show may be taken to have contained a reasonably representative collection—into fairly definite groups. A main division may be made between endless-track tractors and wheeled tractors. At Cardiff the latter outnumbered the former by 4 to 1. Similarly a division might be made between tractors pure and simple and motor ploughs. If it be made, the tractors outnumbered the ploughs again by about 4 to 1, but the distinction is to some extent artificial and is difficult to maintain. In all cases we think the motor ploughs were convertible into tractors by fitting a frame with rear or forward wheels. In ploughing, or other cultivation, it is probably an advantage that the plough or cultivator should be attached directly to the machine and not merely towed, but as against this the work involved in putting the machine to different classes of work is clearly greater when parts have to be unbolted and new parts fitted, as against the mere hitching on of a new machine for new work.

Considering for the moment the wheeled tractors only, it will be found that they can be divided up into fairly definite groups. A broad division is into three or four-wheeled types, of which the latter outnumber the former by more than 2 to 1. The four-wheeled type is distinctly favoured by the American builders, and there is at least one American four-wheeled machine that has superseded a three-wheeled model by the same builders. Beyond the broad division between three wheels and four wheels, subdivisions can be made into tractors with built-up frames and those with a type of box structure in which the crank chamber and back axle casing form the main frame of the machine. Again, a division might be made between tractors with front and those with rear-wheel steering. It is unnecessary, however, to proceed to any greater lengths with this classification into types. What we have wished to illustrate is the great variation now existing and incidentally to lead up to the fact that through all the divergence to be seen there does even now appear to be development towards a definite form.

It is not suggested that there is necessarily anything final in the matter, but broadly we suggest that there is evidence of the evolution of a tractor having four wheels, steering on the two leading wheels and driving by means of pinions working on internal spur rings in the rear wheels. An enclosed differential and gear-box is fitted giving two speeds forward and reverse. The engine is of the four-cylinder vertical type arranged to start on petrol and run on paraffin. A considerable proportion of the American machines have two-cylinder horizontal *vis-a-vis* engines, but one well-known maker has abandoned it for a four-cylinder vertical type. By far the greater number of the tractors have frameworks built up of merchant sections, but a type has appeared represented, for instance, by the Fordson, Austin and Wallis in which the main frame is formed by the crank chamber and back axle casing in the manner we have already referred to. A final point we may mention is that on the whole the British builders fit a higher speed engine than is seen in the American models. There are many exceptions to this rule on both sides, but broadly it is in evidence. In view of the very severe conditions with which any farm tractor may at any time have to deal, it is doubtful if it is desirable to run the engine "all out" in normal working, and a considerable reserve capacity is likely to be very useful.

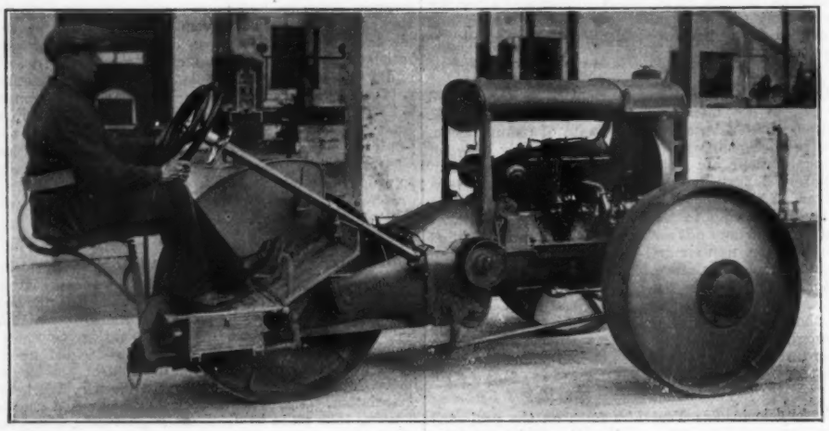


FIG. 7. THE GLASGOW FARM TRACTOR; THE D.L. MOTOR MANUFACTURING CO., LTD., MOTHERWELL.

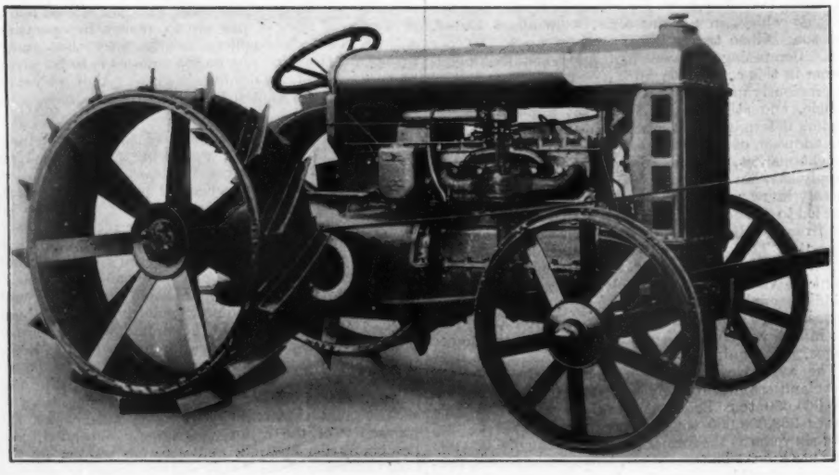


FIG. 8. THE FORDSON TRACTOR; MESSRS. HENRY FORD AND SON INC., CORK.

Turning now to details of some of the tractors exhibited we will in the first instance deal with an example which gets away from the more or less standard class, the general lines of which we have indicated above. We wish to deal with this model first, not only in virtue of its great intrinsic interest, but because it accentuates a matter which is of importance in all tractor design. The tractor to which we now refer is shown in Fig. 7, above. It is known as the "Glasgow," and was shown by the makers, the D. L. Motor Manufacturing Company, Limited, of Toll-street, Motherwell. This tractor, as will be seen from the illustrations, is of the three-wheel type, but its very special features are that all the wheels are driving wheels, and that it has no differential. The advantage of this arrangement clearly is that the whole of the weight of the tractor is available for pulling. The makers of the Glasgow tractor point out, however, that when a tractor is driven by the back wheels only, the reactions due to driving tend to raise the front end, and when front driven tend to raise the back end and claim that only when all wheels are driven can the tractor remain stable when pulling heaving. This question of the tendency to raise the front end of the tractor with rear wheel driving is of importance, and has given much trouble, cases of tractors completely turning over backwards being not unknown. It is clear that if the point of attachment of the plough is above the back axle this rearing is likely to take place, but even with the plough attached low down the stalling of the rear wheels may still have the same effect. The driving of all wheels appears desirable from this point of view.

The Glasgow tractor, as will be seen from the illustration, is of the enclosed type, in which the crank chamber and similar parts act as a main frame. It is fitted with a four-cylinder, 4½ in. bore by 5½ in. stroke engine, which drives through a gear-box in the usual way, giving forward speeds of 5 miles and 2½ miles an hour and reverse of 2¾ miles an hour. The gears run in oil. The final drive is effected by bevel gears on both the front and rear axles. The place of the differential on the front axle is taken by a simple ratchet device on each of the wheel hubs. This allows either wheel to overrun the other. When turning the inner wheel speed follows that of the engine, and the outer wheel simply runs at a speed dictated by the radius of the curve. It will be noted that with this arrangement no power is lost when turning, the outer free wheel simply acting as a steering wheel. The rear wheel

is concave and stabilises the main structure, which is pivoted on the front axle. Further, a stabilising device is attached to the front axle to keep the engine unit always in an upright position. The tractor weighs 3,600 lb.

Fig. 8, on page 12, shows the Fordson tractor, which was exhibited by Norton's Agriculture, Limited, of Llandrindod Wells, Radnorshire. Messrs. Henry Ford and Son's London office is at 59, Shaftesbury-avenue. This tractor, as will be seen, is also of the type in which there is no independent frame. The main body of the machine is formed by the crank chamber and cylinder casting and the rear transmission housing. The engine is of the four-cylinder vertical type, the cylinders being of 4 in. bore and 5 in. stroke. The normal speed is 1,000 r.p.m. Thermo-syphon cooling and a water-filled air washer are fitted. The engine is arranged to start on petrol and run on paraffin, and there is an exhaust-heated vapouriser. The clutch is of the multiple disc type running in oil, and the gear-box, of the sliding type, gives three speeds forward and one reverse. A four-pinion bevel type differential is fitted, with a divided rear axle on motor-car lines. The tractor is not fitted with a brake, as it is not intended for road work. Low gear and engine control are used for short road travel such as may be required in connection with farm work. The high gear gives a speed of 8 miles an hour. The tractor weighs 2,800 lb. As will be seen from Fig. 8, the tractor is fitted with a pulley which can be used for belt driving a threshing machine or other similar farm work. The whole of the tractors at the show were, we think, without exception fitted with such a pulley.

As an example of a very successful American tractor which approximates fairly closely to the general type which we outlined above, we may refer to the Emerson-Brantingham which was shown on the stand of Messrs. Melchior, Armstrong and Dessau (London), Limited, of 27, Maddox-street, Regent-street, London, W. 1. This is of the four-wheeled type, and is fitted with a four-cylinder vertical engine with cylinders 4¼ in. diameter by 5 in. stroke. The normal engine speed is 900 r.p.m. Enclosed gear running in oil is fitted, giving two forward speeds and one reverse. The final drive on to the two rear wheels is by means of pinions working on internal spur rings on the wheels. These gears work in dustproof cases. The engine has an enclosed governor running in oil and the radiator fan is gear driven, so that possible trouble owing to a slipping belt is avoided. The frame is built up of merchant sections, and a special point is made in the fact that the connections of the draw-bar for towing is made forward of the rear axle, tending to minimise any tendency for the front end to lift. The machine weighs 4,355 lb.

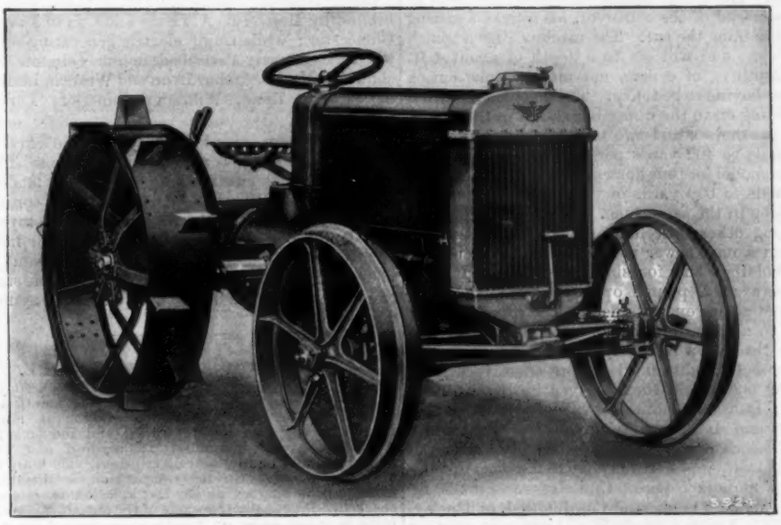


FIG. 9. THE AUSTIN FARM TRACTOR; THE AUSTIN MOTOR COMPANY, LTD., BIRMINGHAM.

FIG. 10. BJERING'S TRENCH DIGGER FOR AGRICULTURAL DRAINS.

The "Saunderson" is a British tractor somewhat on the same lines as the one above, except that it has a two-cylinder engine. It was shown by the makers, the Saunderson Tractor and Implement Company, Limited, of Elstow Works, Bedford. There was, we think, but one other British machine at the show with a two-cylinder engine. The Saunderson engine has cylinders 5½ in. bore by 8 in. stroke, and runs at 750 r.p.m. The frame is built up of rolled sections and the drive to the rear wheels is through the back axle. The gear gives three forward speeds and one reverse. This is a somewhat heavier type of machine than those we have dealt with above. The 23-h.p. to 25-h.p. model weighs 5,600 lb., but a winding drum is fitted making it somewhat more of a general-purpose machine. A tractor of generally the same class, the "Alldays" was exhibited by Messrs. Alldays and Onions, Limited, of Matchless Works, Birmingham. This weighs 6,384 lb. It has three forward speeds and one reverse, and is fitted with a winding drum. Final transmission is by chain. Brakes are fitted for road haulage.

An interesting American tractor, which goes by the name of the "Wallis, Junior," was shown by the Ancona Motor Company, Limited, of 78–82, Brompton-road, London, S.W. 3. This is of the three-wheeled type, driving on the two rear wheels, but its special feature lies in the construction of the main frame. This is built up of plate in the form of a tube carrying the engine crankshaft and transmission gear inside. In a sense the construction is on the lines of the tractors illustrated in Figs. 7 and 8, which we have already dealt with, but with the considerable difference that, as we have said, the main trunk is built up of plating and was not formed with castings. This tractor weighs 3,000 lb., and it is claimed that it has a draw-bar pull equal to its weight. This is stated to be due to the great weight-saving following the use of the special frame. A four-cylinder, 4¼-in. by 5½-in. engine, is fitted, running at 900 r.p.m. Another fairly light tractor, American built to British designs, is known as the "Garner." It was exhibited by Messrs. Henry Garner, Limited, of Moseley Motor Works, Birmingham. This has a built-up frame, and four-cylinder, 4¼-in. by 5¼-in. engine running at from 900 r.p.m. to 1,200 r.p.m. The rear wheels are on a floating axle and three forward speeds and reverse are given. It weighs 3,808 lb.

The Austin Motor Company, Limited, of Northfield, Birmingham, showed a new tractor, which we illustrate in Fig. 9, annexed. This tractor is of the trunk frame class to which we have referred above. A four-cylinder, 3¾-in. by 5-in. engine is fitted, running at 1,200 r.p.m. It runs on paraffin with petrol starting. The clutch is of the Austin steel type with Ferodo segments, and the gear-box gives two forward speeds of 2½ miles and 4½ miles an hour and a reverse of 2 miles an hour. Final drive is through a differential on motor-car lines. The control arrangements consist of a throttle lever just below the steering wheel, a clutch pedal, gear-changing lever, which moves sideways, and two levers which apply brakes direct to the rear wheels. The tractive effort of the machine is taken through a yoke which brings the pull close to the point at which it is developed, and care has been taken to dispose the weight of the tractor so as to minimise danger of rearing. These are points we have referred to in general terms above. The tractor weighs 2,912 lb.

It is not possible for us to deal with the whole of the tractors which were shown, but before passing on to other matters we would like to say something of the machines which can be more directly described as motor ploughs and would also like to mention such of the endless track tractors as we have not yet dealt with. Motor ploughs—that is, machines in which the plough forms an integral part of the tractor and is not simply hitched on behind—were shown by Martin's Cultivator Company; the Crawley Agrimotor Company, Limited, of Saffron Walden, Essex; British Empire Motors, Limited, of 4 to 6, Star-road, West Kensington, W. 14 (the "Moline"); and Messrs. C. Santler and Co., Limited, of Malvernia Works, Malvern Link. Appliances of this type have the obvious advantage that in general the width of the headlands, left at the end of the field during ploughing, will be reduced, since the overall length of the ploughing equipment is less than with a tractor and an independent plough. A further point is that, speaking generally, the effect of travelling over the land, which is an essential feature of all tractor ploughing, is less with a motor plough than with an independent tractor. In most cases the total weight will be

less with a motor plough and there will be fewer wheels travelling over the ground. The effects of wheeled traffic will depend very much on the nature of the land and as the independent tractor is more convenient for general service, the relative advantages of the two types of machine will vary in different cases.

Martin's Cultivator Company's motor plough we described in our last issue. It is an endless-track machine. The Crawley "Agrimotor" is a three-furrow motor plough. The tractor portion has two driving wheels, and there is a steering wheel behind the plough. It has two forward speeds and reverse. The "Moline-Universal" is a somewhat similar machine, but has two land wheels forward of the plough, one of which runs in the furrow. It has one forward speed and reverse and the final transmission is by internal spurs on the driving wheels in the manner we have already referred to. The "Santler" is quite a novel machine, and is fitted with ploughs both before and behind, so that when in work the machine is not required to turn round. The ploughs can be raised and lowered, and when working down a field the forward plough is raised and the one behind is working, but when the end of the field is reached the working plough is lifted and the other lowered, and the machine starts off in the other direction. The headlands are stated to be reduced to 3 ft. by this arrangement, and clearly considerable time should be saved.

Endless track machines were shown by Martin's Cultivator Company, Messrs. Clayton and Shuttleworth, Messrs. H. G. Burford and Co., Ltd., of 16, Regent Street, London, S.W. 1 (The Cleveland), and Messrs. Blackstone and Co., Ltd., of Stamford. The two former of these we described last week, and the Martin machine we have again referred to immediately above. The Cleveland tractor is of American build. It is fitted with a four-cylinder 3¼ in. by 5½ in. engine and runs on paraffin, starting on petrol. One forward speed and one reverse are arranged for, the engine driving through a gear box to a differential and through jack shafts to the final transmission contained in the rear driving wheels. Steering is obtained by employing one or other of two band brakes which lock one or other of the two endless track creepers. The machine weighs 2,912 lb. The Blackstone tractor is fitted with the firm's air-blast type of paraffin engine, and carries an air bottle. It can be started cold on paraffin. The engine is of the three-cylinder type with cylinders 5 in. diameter by 6½ in. stroke. The gear box gives two forward speeds but no reverse, reversing being performed by reversing the engine. Steering is obtained by controlling the differential and consequently the relative speeds of the two endless track chains.

Leaving the question of tractors and turning to some of the more miscellaneous exhibits which were shown at Cardiff we may first mention an interesting potato planting machine called the Albion, which was on the stand of Messrs. Harrison, McGregor and Co., Ltd., of Albion Iron Works, Leigh, Lancashire. This appliance consists of a two-wheeled carriage, pulled by a horse. As it moves forward a drill is opened by a V-shaped spud which is carried below the carriage and in contact with the ground. Its vertical position can be adjusted to regulate the depth of drill. Immediately behind the spud an endless conveyor delivers the seed potatoes into the drill. At the point of delivery the conveyor buckets are moving vertically, but at the top of the carriage they take an horizontal course and are loaded by the operator from a tray placed immediately in front of her and behind the conveyor (the machine is one very suitable for use with girl labour). The drill is closed after the potatoes are in position by means of a couple of inclined rotating discs which sweep back the earth which has been displaced by the spud. The girl feeding the conveyor has no other work to attend to, as the steering and driving of the planter is looked after by a second girl, or a boy, in charge of the horse. The girl feeding the conveyor is provided with a seat and travels with the machine. As the conveyor is gear driven from the main axle, variations in the speed of travel of the machine do not affect the distance apart at which the potatoes are planted.

A novel machine or appliance for trench digging for laying agricultural drain-pipes was exhibited by Mr. H. Bjering, of the Alliance Trading Company, of Holland House, Bury Street, London, E.C.3. We illustrate this in Fig. 10, on page 13. It consists of a frame carrying a U-shaped cutting bit at its forward lower end. It is drawn by two horses, which walk one on either side of the trench which is being dug. The bit scoops up a continuous layer of soil which travels up a conveyor carried by the machine and driven by the single wheel which runs in the trench. At the top of the conveyor the soil is discharged on to a chute, which throws it off on to the ground clear of the trench. The depth of cut is regulated by an adjustable shoe in front of the machine, which can be clearly seen in the illustration. The driver stands on a small platform at the lower end of the conveyor, his weight assisting in maintaining the cut. The machine digs a trench 7 in. wide, and will cut to a depth of about 4 ft. This depth is, of course, not made in one cut, a number having to be taken. The machine is steered by holding on to the upper bar shown in the figure. With two horses and two men the digger will cut 300 yards to 400 yards per day about 4 ft. deep. A large model for four horses and three men will dig 400 yards to 600 yards of trench 12 in. wide and 4 ft. deep in the same time.

Among other miscellaneous exhibits we should mention a man-power plough intended for use on small-holdings and for similar purposes. It consists of a small plough operated by a wire rope anchored at one end of a field. The rope is wound up on to a drum on the plough worked by a long handle through a ratchet gear. The appliance is simple, and should afford a more effective way of utilising man-power than is given by the ordinary spade. It was exhibited by Mote's Man-Power Plough and Implement Company, of Poulton-le-Fylde, Lancashire. As this exhibit introduces the matter of wire ropes, we may say that a good display of their manufactures of this class was made by Messrs. William Cooke and Co., Limited, of Tinsley, Sheffield. Another Sheffield exhibit was that of Messrs. Hadfield's, Limited, who showed a stone-breaking plant and a disc crusher in operation. As other examples of engineering matter we may mention a display of solid-drawn steel tubes by the British Mannesmann Tube Company, Limited, of Salisbury House, London Wall, E.C.2, and the Blackler mechanical hammer which has already been described and illustrated in our pages, and which was shown by Messrs. Blackler, Limited, of Stalybridge. Injectors, semi-rotary pumps, &c., were exhibited by Messrs. W. H. Willcox and Co., Limited, of Southwark Street, London, S.E.1. The Ironite Company, Limited, of 11, Old Queen Street, Westminster, S.W.1, showed their Ironite cement, while Messrs. Turner Bros. Asbestos Company, Limited, of Rochdale, made a good display with their asbestos building sheets and tiles. This material is very suitable for much agricultural work.

There were a number of agricultural and traction engines exhibited, in addition to those dealt with in our previous article. From among these we may mention the internal-combustion cable-ploughing engine shown by Messrs. Walsh and Clark, Limited, of Guisley, Leeds, the steam tractors of Messrs. W. Tasker and Sons, Limited, of Andover, Hants, and the traction engine shown by Messrs. Charles Burrell and Sons, Limited, of Thetford, Norfolk. Steam tractors and ploughing engines were also exhibited by Messrs. J. and H. McLaren, Limited, of Midland Engine Works, Leeds, and a traction engine by Messrs. Wallis and Stevens, Limited, of Basingstoke. Similar material was shown by Messrs. Ransomes, Sims and Jefferies, of Ipswich, while Messrs. Barford and Perkins, Limited, of Peterborough, exhibited several of their well-known motor road rollers. Suction gas plants were represented by Messrs. Crossley Bros., Limited, of Openshaw, Manchester, and Messrs. Fielding and Platt, of Gloucester. On the stand of this latter firm Messrs. Stothert and Pitt, of Bath, exhibited a new form of rotary pump known as the Feuerheerd. We propose to deal with this pump in detail in a later issue.

Oil engines, mostly of small size, were exhibited by a large number of firms. Prominent among these we may mention Messrs. Petters, Limited, of Yeovil, who showed their semi-Diesel type and also their direct reversing marine type. Small petrol and paraffin engines were on view on the stands of The Bristol Carriage and Wagon Company, Limited, of Bristol; the Garrard Engineering and Manufacturing Company, Limited, of 17, Grafton Street, London, W.1; the Hamworth Engineering Company, Limited, of Poole, Dorset; the Keighley Gas and Oil Engine Company, Limited, of Keighley; the National Gas Engine Company, Limited, of Ashton-under-Lyne; the Fairbanks Company, of 15, Mallow Street, Old Street, London, E.C.1; and Messrs. Fairbanks, Morse and Co., Limited, of 87, Southwark Street, London, S.E.1. Petrol engines coupled to pumps and an example of the well-known "Lister Bruston" electric lighting plant were exhibited by Messrs. R. A. Lister and Co., of Dursley, Gloucester; while small electric generating sets of the type recently described in our columns were shown by Messrs. Arthur Lyon and Wrench, Limited, of Victoria Road, Willesden Junction, London, N.W.10.

In conclusion, we should say that an excellent electrical exhibit, consisting of a house fitted throughout with electrical appliances, was made by the Cardiff City Electricity Department, in conjunction with the South Wales Electric Power Company. We should also say, in connection with our notice of last week, that Messrs. Marshall, Sons and Co. point out that our Fig. 2 shows their 5-ton steam tractor and not their 7 n.h.p. traction engine as described.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—An easier tendency is manifest in iron and steel production. Stock-taking is almost general throughout the big works, and movement is restricted to the minimum. In pig-iron and basic material of all qualities and descriptions, values are still on the up-grade. Serious competition is threatened from outside sources unless the inflation of prices is checked. Practically the whole of the output of common irons is going away on contract account. The small tonnage available for open market disposal is readily sold at maximum values. Current consumption is nearly on a par with output. Export requirements are more numerous, but makers have little to offer, and few new openings are being followed up. Restriction of output, particularly of bars and other finished iron, is a subject of widespread complaint among steel makers. Responsibility is cast upon the alleged diminution of effort among the workers at the mills and furnaces. While some allowance has to be made for temptation on the part of producers to maintain values at their current high level by a careful adjustment of supply, from judicious inquiry there appears no doubt that labour is adopting an easier attitude, particularly as regards heavier classes of work. A further advance is forecasted in South Yorkshire billets, now quoted as follows: Siemens acid, 17*l.* 12*s.* 6*d.*; Bessemer acid, 17*l.* 12*s.* 6*d.*; hard basic, 15*l.* 12*s.* 6*d.*; soft basic, 14*l.* 12*s.* 6*d.* The heavy trades show several weak patches. Orders are wanted in the crucible and electric steel branches, which are working not more than an average of four days a week. The total volume of business booked within the last few months compares not unfavourably with similar periods of pre-war years, but as facilities for output have been largely extended, more work is wanted to secure constant activity. Stocks of special steels remaining from war purchases are gradually disappearing. Until they are wiped off, new business is likely to continue restricted. Improved business with France and Sweden is anticipated following the removal of restrictions. Shipbuilders' and foreign railway requirements continue heavy. New bookings for tramway steel and manganese specialities are moderate. One of the most marked improvements which promises to become general is steel forgings and castings for automobile construction. Orders continue literally to pour in in the lighter trades. Several new extensions of plant have been planned to meet the heavy call for files and wire. A United States firm is displaying a keen interest in cutlery-grinding machinery.

South Yorkshire Coal Trade.—Best steam hards are in strong request by all classes of home consumers. Railway companies are making special efforts to build up reserves. Cobbles, nuts and slacks all meet with a ready sale, particularly on contract account. Weakness is still manifest in regard to small fuels, but this is strictly confined to inferior qualities. House coal continues a strong market. Orders for winter stocking purposes have come forward much more freely within the past fortnight. Steel cokes are in fairly good demand. An improvement is reported in blast furnace coke. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best silkstone, 27*s.* 0*d.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*, Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls 13*s.* to 14*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Little change of any moment falls to be recorded in the Scotch steel trade, and conditions are very similar to those of a week ago. With the signing of the Peace Treaty the atmosphere is now a bit clearer and the future may be looked forward to with a little more confidence. The world's markets will now be opened up for trade and there will soon be a much-needed improvement in transport facilities. Before we can hope to extend our present small export trade there will require to be a vastly increased output, as the home consumer still seems able to absorb all that the mills can turn out. Especially is this the case with regard to ship plates, and producers are so well booked up that early delivery cannot be promised, and in many cases orders are being accepted on the understanding that delivery may not be had for about a couple of months. A different state of affairs exists in the case of sections, and although a fair amount of business is going through there is really no pressing demand. Steel sheets, which have recently had quite a good run, are not now in such great request, nevertheless there is still a fair amount of activity in this branch of trade as producers have freedom of action and are prepared to meet buyers. Galvanised sheets are still rather dull, but some signs of improvement are noticeable, and a turn for the better is very probable.

Malleable Iron Trade.—A good, steady business is general in the malleable iron trade in the West of Scotland, and the local demand takes up most of the present output. Prices are high on account of the dearness of raw material and the heavy oncost charges. Order books are well filled and steady running is ensured for some time, but perhaps the greatest trouble at present is the reduced output due to the rearrangement of shifts consequent on the 48 hours' week. This reflects upon deliveries and prompt parcels cannot therefore be offered big makers.

Scotch Pig-Iron Trade.—There has been no falling-off in the demand for Scotch pig-iron during the past week, and hematite is being delivered to the steel makers as fast as it can be turned out. Foundry iron is also being absorbed very quickly by the home consumers and little remains for shipment purposes. Prices have still a strong tendency to advance even beyond their present excessively high figure.

Scotch Shipbuilding.—The Scotch shipbuilding yards had quite a respectable output during the past month, when 44 vessels, aggregating 91,987 tons, were launched. In comparison with the output for May, when nearly all the new vessels were to order of the Government, the majority last month were for private owners. The following are the figures for the different districts for June, and also the totals for the half-year :—

	June.		Six Months.	
The Clyde ...	37	83,907	144	264,806
The Forth ...	3	4,900	17	23,361
The Tay ...	2	2,780	8	10,758
The Dee ...	2	400	28	5,187
Totals ...	44	91,987	197	304,112

The Clyde figures are interesting, and are not only nearly up to the large tonnage of April, when the totals were 34 vessels of 85,774 tons, but make up the largest tonnage for the month of June since the year 1906 (excluding the war period), when the output was 36 vessels of 124,544 tons. Included in the total for last month are a number of vessels which should have been launched in May but which were delayed owing to the tug-boat men's strike. Taking the figures for the two months the average is over 50,000 tons, which is very satisfactory. The returns for the six months of this year compare very favourably with those of 1914 and show that the Clyde is fast returning to its pre-war standard. During the month of June a number of new contracts were placed, but only some of these have been made public. The following are reported: Messrs. Ferguson Brothers Port Glasgow, 5 cargo steamers, and Messrs. Murdoch and Murray, Port Glasgow, 5 cargo steamers. The total tonnage of these 10 vessels will be about 42,000 tons.

Scotch Coal Trade.—The Scotch coal trade is practically without change of any note. In some instances the supply is rather above the demand, and the wise buyer is managing to lay a trifle aside for future use. The export business is slightly better, but we do not yet seem within measurable distance of the days of the large shipping trade. Prices are firm, and with an upward tendency.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Cleveland pig-iron prices are unaltered, but as there is a feeling that they may rise at an early date, sellers are very cautious in their dealings, and do not care to commit themselves extensively. There is a little more No. 3 available for disposal, one or two furnaces having been working better lately, but generally the superior qualities of iron are still scarce. Forge, mottled, and white descriptions, however, are comparatively quite plentiful, and are offered freely for practically any delivery. Export licences are still issued sparingly, but they are somewhat less difficult to obtain than they have been. Several foreign buyers, however, who used to deal in this market are now taking supplies from elsewhere. For home consumption, No. 3 g.m.b. and No. 4 foundry are 160*s.*, No. 1 is 164*s.* and No. 4 forge 158*s.*; and export rates re 5*s.* above these quotations.

Hematite Iron.—The announcement of 10*s.* advance in East Coast hematite, which brings rates to the highest figures ever recorded, has occasioned no surprise seeing that cost of production has increased so heavily. Buyers are quite prepared to pay the higher rates, and, in fact, demand shows no abatement. Nos. 1, 2 and 3 are now 200*s.*, and No. 1 is 202*s.* 6*d.* for home use; whilst mixed Nos. are 205*s.*, and No. 1 is 207*s.* 6*d.* for export.

Coke.—Local demand for coke keeps on a substantial scale, and as the supply continues more than ample, there is a good deal of business passing. Average blast-furnace quality is 39*s.* at the ovens, and low phosphorus sort 41*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—There is no new feature of moment in the manufactured iron and steel industries. Inquiries from abroad are still rather numerous and heavy, and home demand continues good. Labour troubles still hamper producers, but works are kept going wonderfully well under the conditions prevailing. Export prices are not fixed, but they are understood to be rather higher than the following, which govern the home trade:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.*; strip iron, 21*l.* 15*s.*; ship rivets, 27*l.* 10*s*; steel ship, bridge and tank plates, 17*l.* 15*s.*; steel angles, 17*l.* 5*s.*; steel joists, 17*l.*; steel hoops, 23*l.* 5*s.*; heavy steel rails, 16*l.*; galvanised sheets, 27*l.* 10*s.*

Foreign Ore.—The action of the Controller of Shipping whereby ore freight from Bilbao has been reduced, has given general satisfaction, and promises to assist materially expansion of trade with Spain. As much as 31*s.* had been paid Bilbao-Middlesbrough, but now steamers are being chartered at 29*s.* The change is due to British vessels being forbidden to come home light. Under the altered conditions best rubio may be quoted round about 58*s.* 6*d.* c.i.f. Tees.

Shipments of Iron and Steel.—The shipments of iron and steel from the port of Middlesbrough for June, whilst small, were certainly better than generally looked for. They totalled 41,327 tons, of which 37,488 tons went to foreign ports and 3,839 tons to coastwise customers. The clearances consisted of 16,310 tons of pig-iron, of which 14,360 tons went foreign, and 1,950 tons coastwise; 2,172 tons of manufactured iron, of which 2,107 tons went foreign, and 65 tons coastwise; and 22,845 tons of steel, of which 21,021 tons went foreign, and 1,824 tons coastwise. Italy was the largest importer of pig-iron, receiving 6,200 tons; Belgium being second with 4,120 tons, and Japan third with 2,485 tons. The Cape took the largest quantity of manufactured iron—699 tons. India was by far the best customer for steel, importing 8,658 tons; whilst New South Wales took 2,635 tons; Japan, 1,775 tons; Victoria, 1,459 tons; the Straits, 1,359 tons; and Natal, 1,042 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Labour troubles have seriously interrupted business on the coal markets and dislocated the arrangements of operators. Arrivals and sailings at the Cardiff Bute Docks have been held up by a strike of dock gatemen, and at Barry a partial suspension has taken place because of a stoppage on the part of the riggers, dock pilots and boatmen in an effort to force the employers to grant them a 20 per cent. increase on their weekly earnings. It is also stated that the Coal Controller intends to reduce by 7,000,000 tons per annum the export of coals from South Wales. It is also stated that the railways are unable to deal efficiently with the transport of more coal than they are now handling for inland purposes, and a scheme has been devised to become operative after July 15 by which a greater quantity of coal will be conveyed from the Bristol Channel and other coal-exporting centres to specified home ports for inland distribution. The trouble at the docks has resulted in a number of stoppages in the coalfield through lack of empty wagons. The strike of dock gatemen at Cardiff ended last night, consequent upon a conference between the Railway Executive, dock owners and representatives of the men, but the Barry stoppage continues. Despite the interference in the shipment of coal collieries still demand round 55*s.* for large coals for allied destinations and from 40*s.* to 45*s.* for small steams, as they anticipate a heavy demand immediately the labour troubles are disposed of. The inquiry from neutral countries is restricted, but this has little influence as the requirements of the Allies are more than sufficient to absorb available supplies. Collieries have been instructed to accept such delivery of pit-wood as the South Wales Pitwood Allocation Committee may from time to time determine, until each colliery shall have accumulated a stock equal to at least eight weeks' normal consumption; further, that additional stocking ground shall, if necessary, be taken up for such purpose.

Newport.—There is an active demand for Monmouthshire coals, and prices are firm on the basis of 55*s.* for large Black Vein, Western Valley, Eastern Valley descriptions, and from 37*s.* 6*d.* to 43*s.* 6*d.* for smalls, according to quality.

Miners' 7-Hours Day.—In regard to the revision of piece-work rates in connection with the shorter working day which will become operative from July 16, there was failure to agree at a meeting of the Welsh Coal Board held at Cardiff yesterday. The Coal Controller suggested a maximum increase of 10 per cent., and the workmen's representatives demanded an increase of 15 per cent., in order to enable piece workers to maintain their earnings at the level which obtained when working hours were eight per day. The miners will hold a conference next week to consider the position.

NOTICES OF MEETINGS.

THE ROYAL INSTITUTION.—Monday, July 7, General Meeting, at 5 p.m.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Victory Meeting, Newcastle-upon-Tyne, July 8, 9, 10 and 11:—Tuesday, July 8: 7 p.m. for 7.30 p.m., Banquet in the King's Hall, Armstrong College, Newcastle-upon-Tyne. Wednesday, July 9, 10 a.m., Commemoration Service in the Cathedral Church of St. Nicholas, Newcastle-upon-Tyne, for members of the Institution who have fallen in the war. 11 a.m., Opening Meeting in the King's Hall, Armstrong College, Newcastle-upon-Tyne; presentation of the Honorary Fellowship of the Institution to the Honourable Lady Parsons; Monsieur le Maréchal Foch, O.M.; Admiral of the Fleet, Sir David Beatty, G.C.B., O.M., G.C.V.O., D.S.O.; Field-Marshal Sir Douglas Haig, K.T., G.C.B., O.M., G.C.V.O., K.C.I.E.; The Right Hon. Lord Weir of Eastwood, P.C.; The Right Hon. Sir Joseph Paton Maclay, Bart., P.C. Reading and discussion of the following papers: (1) "Women's Work in Engineering and Shipbuilding during the War," by the Hon. Lady Parsons, Hon. Fellow; (2) "A Short Record of the Work of the Principal Industries of the North-East Coast during the War," by Mr. A. H. J. Cochrane; a special Convocation of the University of Durham will be holden in the King's Hall, Armstrong College, for the purpose of conferring Honorary Degrees. Thursday, July 10, 11 a.m., Reading and discussion (in the Literary and Philosophical Society's Lecture Theatre): (1) "Some Developments in Aircraft Design and Application during the War," by the Right Hon. Lord Weir, of Eastwood, P.C., Hon. Fellow; (2) a Lecture by Professor J. C. McLennan, F.R.S. 3 p.m., reading and discussion (in the Literary and Philosophical Society's Lecture Theatre): (1) "The Limits of Thermal Efficiency in Diesel and other Internal Combustion Engines," by Sir Dugald Clerk, K.B.E., F.R.S.; (2) "Dazzling of Ships," by Lieutenant Commander Norman Wilkinson, R.N.V.R., O.B.E. 8 p.m., Reception in the Laing Art Gallery by the Right Hon. the Lord Mayor of Newcastle-upon-Tyne (Councillor A. Munro Sutherland). Friday, July 11: 11 a.m., reading and discussion (in the Literary and Philosophical Society's Lecture Theatre): "Ship-repairing during the War," by Mr. M. C. James, vice-president, and Mr. Launcelot E. Smith, C.B.E., Member.

INSTITUTION OF NAVAL ARCHITECTS' SCHOLARSHIPS.—Two scholarships, of the value of 150*l.* per annum each, and tenable for three years, will be offered this summer, viz.: The Cammell Laird Scholarship in Naval Architecture and the Parsons Scholarship in Marine Engineering. Candidates must be British apprentices in shipyard or marine engine works, between the ages of 19 and 25. Entries close on August 11. Full particulars from the Secretary, Institution of Naval Architects, 5, Adelphi Terrace, London, W.C. 2.

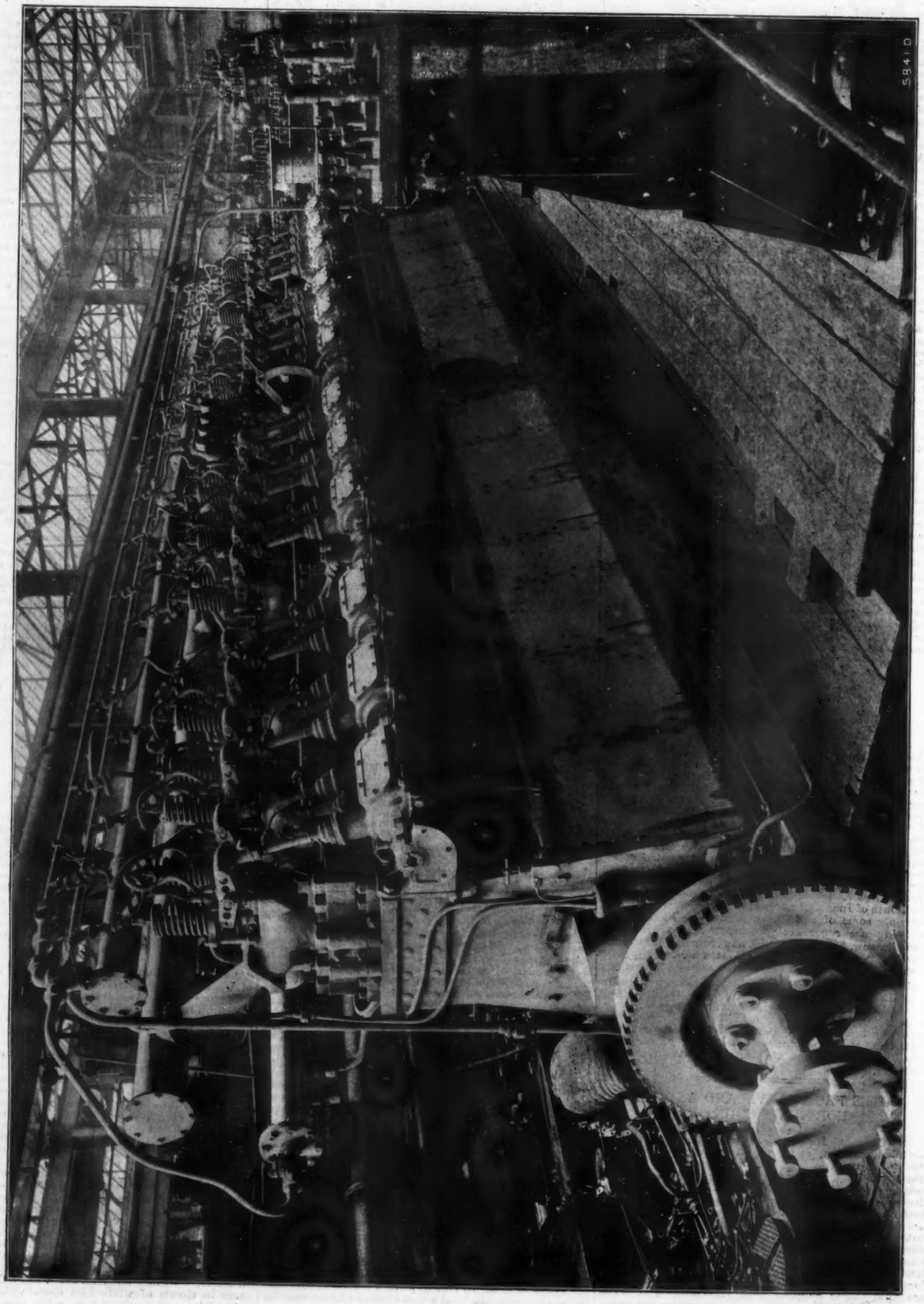
ROYAL AERONAUTICAL SOCIETY.—With the two-fold object of celebrating its jubilee, which was attained in 1916, when celebrations of any kind were inadvisable, and of marking the fact that it has by command of His Majesty, been dignified by the prefix "Royal," the Royal Aeronautical Society decided to give a garden party for its members and their friends. By permission of Mr. Handley Page the function was held at the Cricklewood Aerodrome on Sunday afternoon last. The entertainment provided included exhibition flying and an inspection of a number of Handley-Page machines, as well as lectures, concerts, and an exhibition of aeronautical instruments, &c., arranged by the Technical and Research Department of the Air Ministry. The works and shops of Messrs. Handley Page, Limited, in which machines for bombing and commercial service could be seen in all stages of construction, were also thrown open for inspection. The gathering was well attended, and was in every way a complete success. The society, we may add, has done much useful work during the war, and its growth has been proportional to that of the aeronautical industry, the membership now standing at considerably over 1,000.

LEAD POISONING AND WOMEN.—The susceptibility of women to certain forms of lead poisoning and the dangerous effects upon their children are dealt with in Bulletin 253 of the United States Department of Labour Statistics. Lead poisoning is fairly common in America, but before the war few women had been employed in the various lead industries. In England women are barred from lead works. Some German statistics tended to show that women were not really more susceptible than men, but that the sufferers were in general a weakly, badly nourished type of women, not fit for hard work, who drifted into lead works, and that seems to be confirmed to a certain extent in the United States. In the pottery industry more women suffer from lead poisoning than men; but the men belong to a well-to-do trade union and draw good pay, whilst the women have no organisation and are underpaid. In the tile works of the Zanesville district, where men and women are of the same economic class, and badly paid, women show a slightly greater susceptibility. All statistics seem to agree as to the fact that lead poisoning takes peculiar forms in women, and renders them unfit to be mothers, and that they should not be allowed to have anything to do with lead and lead compounds. The danger lies largely also in the deceptive character of the symptoms and in the individual character of the susceptibility. In the same factory one man had worked for thirty-five years in clouds of white lead dust—which should be impossible—and was still hale, while another man fell ill after two weeks, and was dead in five months.

TWELVE-CYLINDER NON-REVERSING HEAVY OIL ENGINE FOR SUBMARINE BOATS.

CONSTRUCTED BY MESSRS. VICKERS LIMITED, NAVAL CONSTRUCTION WORKS, BARROW-IN-FURNESS.

(*For Description, see Page 8.*)



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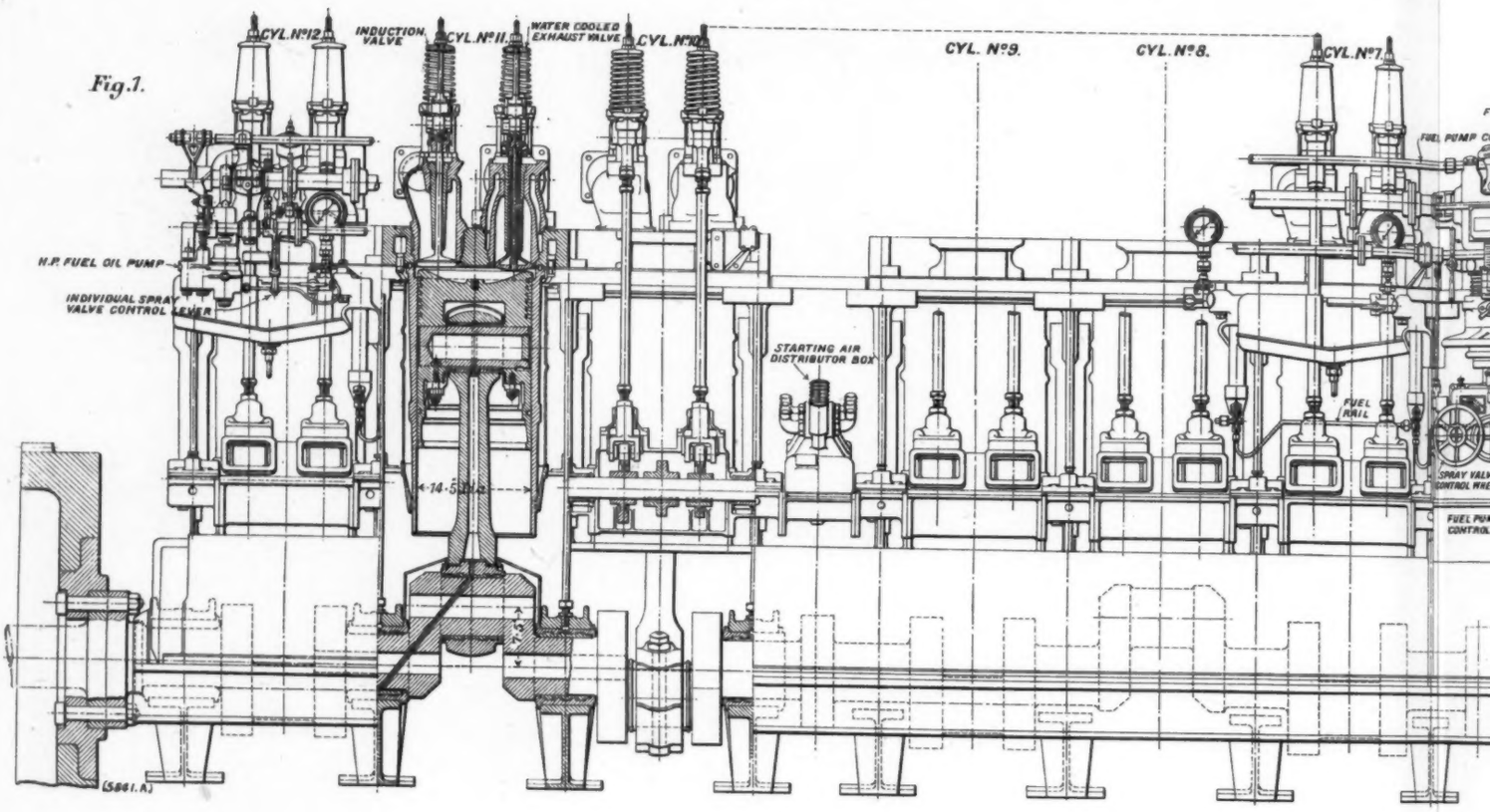

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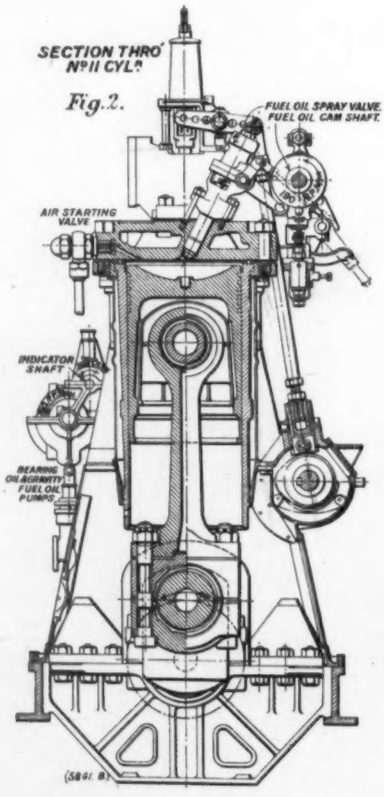

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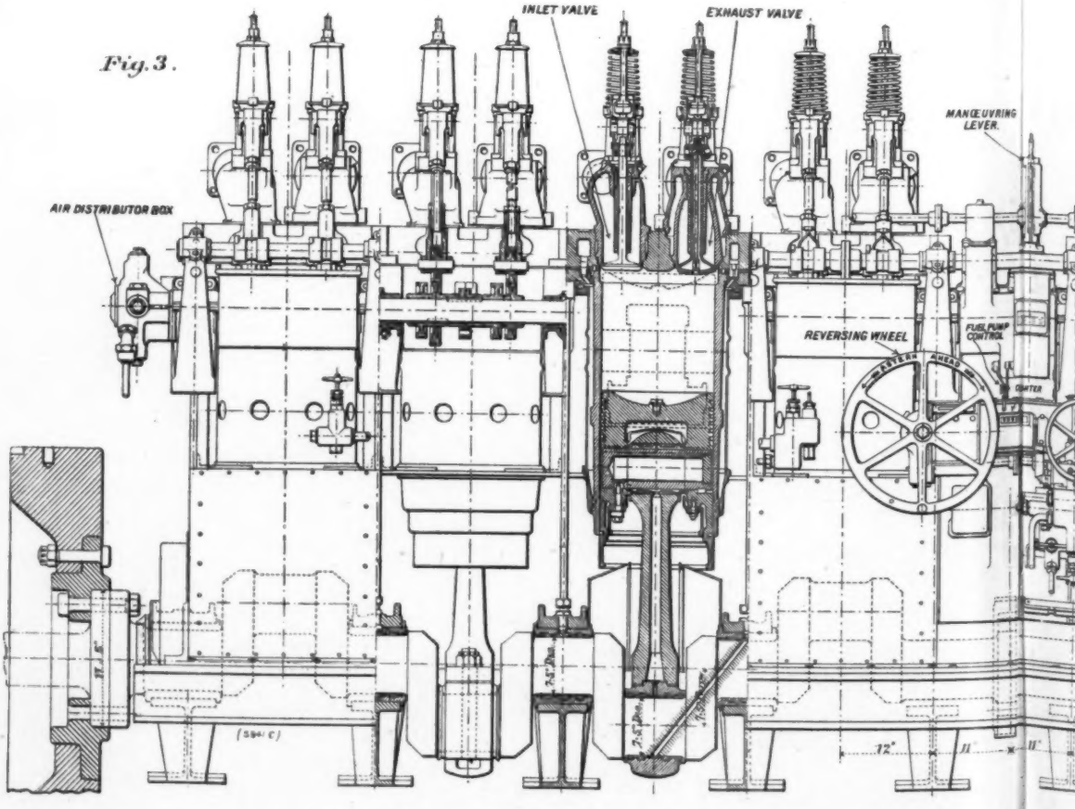

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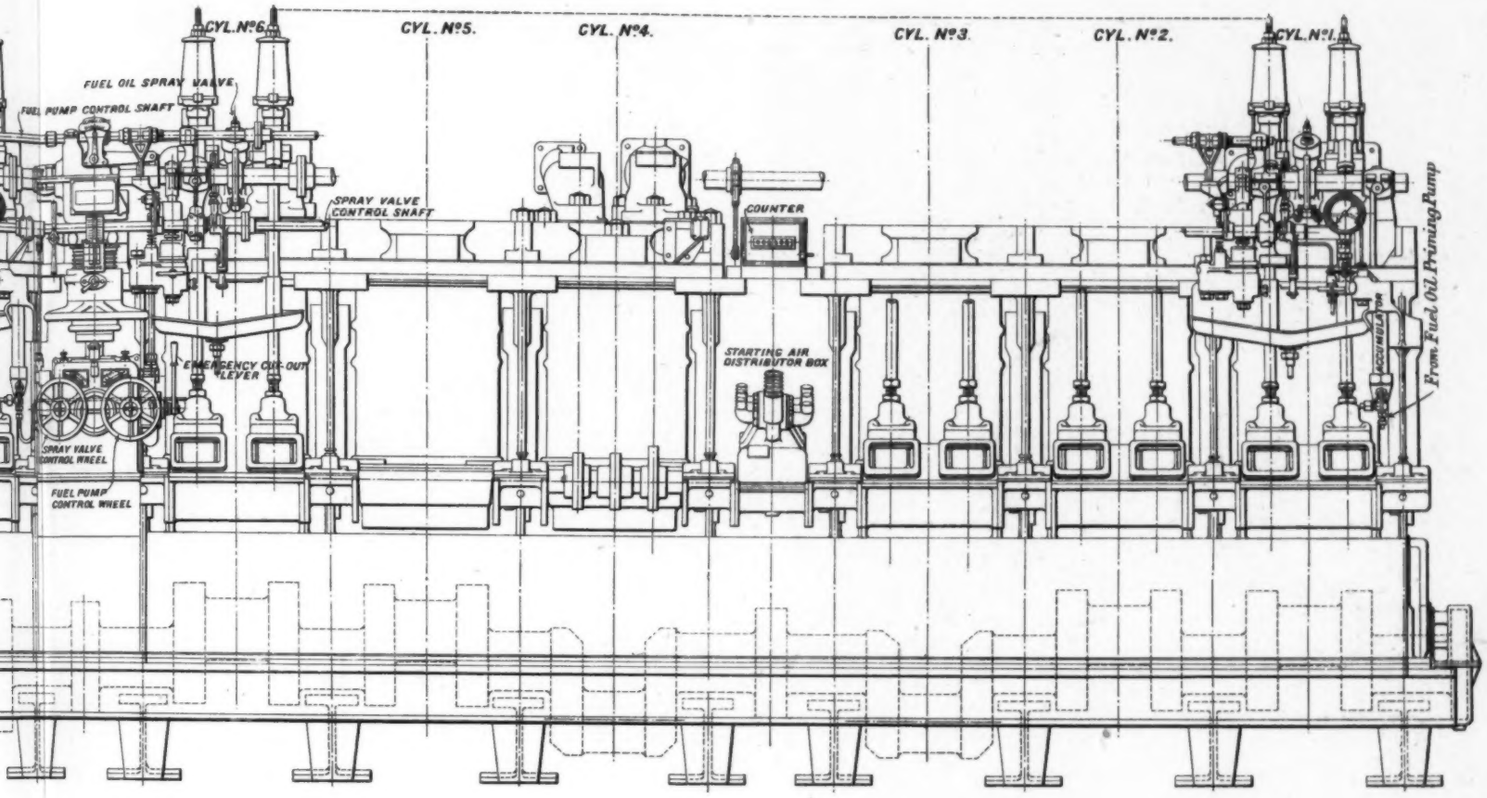

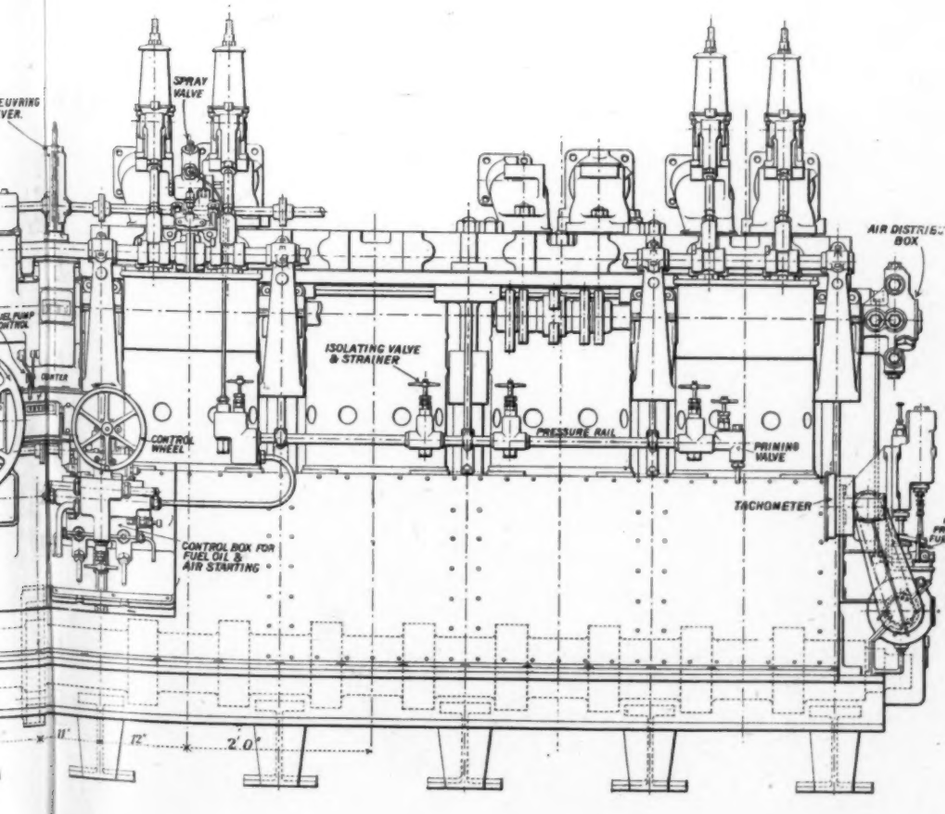

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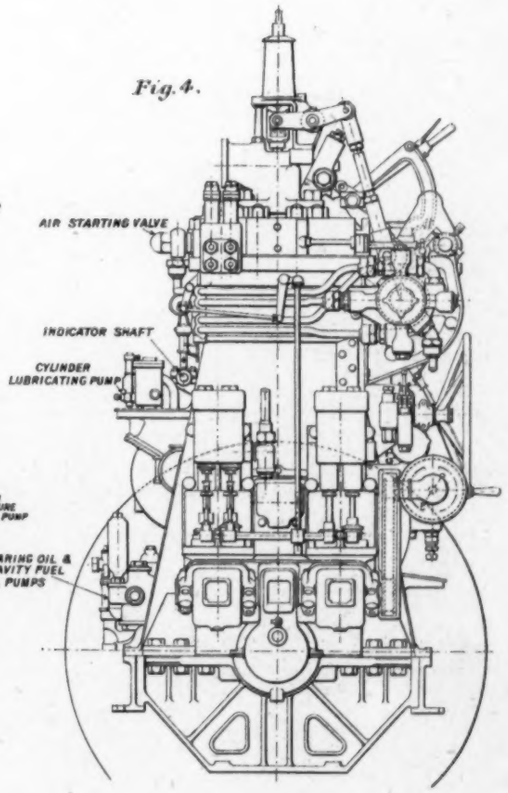

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—9683 and 8598 GERRARD.

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NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 15.

ENGINEERING.

FRIDAY, JULY 4, 1919.

WOMEN IN INDUSTRY.

THE Bill for the restoration of trade union privileges in industry will shortly come before one of the Grand Committees of the House of Commons. It is what is known as an "agreed measure," although trade union leaders themselves recognise that it would not be to the national interests to revert to all pre-war conditions in the factory. When they agreed to forfeit many of their rules and practices in order to speed up the manufacture of munitions, they insisted on a promise that after the war the *status quo ante bellum* would be re-established by Parliamentary enactment. The Government had no alternative than to introduce the Bill now before the House of Commons, but the changes having been effected to augment output, there is established the fact, long since a matter of dispute, that the "ca'canny" procedure restricted the volume of production available for export. Now, more than ever, it is imperative for the stabilising of national finance that we should win back gold in return for exports, and trade union leaders must encourage the workers to meet the country's pressing need, especially as this must advance the prosperity and profit of the working classes themselves. The Bill will be opposed in the interests of those women who have found their vocation in the factory, notably in engineering work, and it is opportune to consider the whole subject of women in industry, and the extent to which their merit as producers and their wages relative to those of men conduce to their retention or displacement in the factory.

Although, from the engineer's point of view, the presence of women in industry is largely a new phenomenon, and raises new problems, there is really nothing new in the matter. Women have always been employed in industry, and in recent years have in some trades considerably exceeded in quantity the number of men. Textiles and clothing are instances. None the less, the largely increased percentage of female labour which has grown up during the war in trades which had generally come to be looked upon as man's special field has introduced a social problem which cannot be ignored. This invasion of the workshop by women has, however, been less widespread than is perhaps sometimes supposed. The special case of munitions may well have given many engineers an exaggerated idea of the extent to which this invasion has taken place over the whole field. According to the Board of Trade there were in July, 1914, 2,178,600 women employed in industry proper in the United Kingdom as compared with 6,301,000 men. These figures do not include domestic service, education, agriculture, employment in hotels and other callings which are not generally described as industrial. In July, 1918, the corresponding figure for women had risen to 2,970,600, an increase of 792,000. Of this latter figure 704,000 are considered to have directly replaced men. These figures refer to a period nearly twelve months ago, but give a good idea of the extent of the accession of women to the ranks of industry. The figures are probably lower than would generally be expected, and at first sight they give the idea that if the large numbers of women who were withdrawn from domestic service and the textile trades during the war are prepared to move back to their old occupations, then in no great while we should be able to settle quietly down to our pre-war condition.

It is much to be feared, however, that matters will not arrange themselves in any such simple way as by the voluntary return of the women to their old occupations. The complexity of the problem to be faced is somewhat obscured by a consideration of the figures for industry as a whole, since in some trades, of which clothing and textile manufacture are the chief examples, the number of women employed decreased during the war. The effect of this is that the figures for the whole of industry do not properly show the great turn-over of female labour which has taken place. The figures for the metal trades give a better idea of the extent of the problem. These figures cover all that can broadly be described as engineering. In these trades the number of women employed in July, 1914, was 170,000, and in July, 1918, 594,000. The change which took place is best illustrated on a percentage basis. In 1914 females formed 9 per cent. of the total number of workpeople in these trades. In 1918 they formed 25 per cent. It is clear that 16 per cent. of the total number of employees in the engineering trades cannot be moved and placed in new positions in other trades in the course of a few weeks or months, and it is equally clear that the metal trades, swollen out of all proportion by the requirements of the war, cannot permanently absorb all these extra women, in addition to the men now returning, unless their scale of production is going to be a different thing from what it was in the first half of 1914.

The figure of 792,000 which has been given as the total accession of women to industry by no means represents the total movement of women into what have usually been considered mainly men's occupations. Transport, for instance, absorbed 99,000 extra women, agriculture 38,000, commerce 429,000, and so on. It is not necessary to go into detail in this matter. All that is necessary is to show that the three-quarters of a million or so extra women in industry are not likely to find it a simple matter to move to some other occupation. The only field in which there would appear to be vacancies for large numbers is domestic service, which lost 400,000 women during the war, and this, unfortunately, is an occupation which appears to have lost attraction. Considering the metal trades in the light of this position, it is of importance to speculate what is to be the fate of the 16 per cent. of extra workpeople of the female sex, and if any considerable proportion of them is likely to remain in the various trades they have entered.

It was said that in July, 1914, 9 per cent. of the employees in the metal trades were women. It is of interest to consider what these women were doing. The report of the War Cabinet Committee on Women in Industry shows that women were before the war employed in wire-drawing, making chains, nails, screws, &c., on light castings, hardware, tinned and japanned goods, in cutlery, including pins and needles. In the cycle and motor trades they constituted over half the workpeople engaged on light-milling, drilling, capstan operations, and hand press work. They were also employed on making hack-saws and files, and on making buttons, hooks and eyes. In electrical engineering they were employed on the manufacture of electricity meters, dynamos, lamps, fittings and switches. They also worked on several components required in the manufacture of small arm ammunition. In connection with light casting they were mainly employed on core making and for many descriptions of hollow-ware and cast-iron goods on finishing processes, such as mounting, painting, polishing, blacking, &c. They were also engaged on turning, screwing and pointing bolts, and on facing and tapping nuts, but not on forging bolts and nuts, or machining nuts.

It will be generally agreed that all this kind of thing is work which women have proved themselves very capable of doing. It is all of a repetition nature and can only be classed as semi-skilled. If our output of manufactured goods is to advance as it ought, there should in the future be a larger field than ever before for women in this class of work. An extension of the woman's field in this direction depends on three things; on the work being available, on the attitude of the skilled men's unions

and on the wages which the women expect to receive. These three conditions represent questions of such difficulty and complexity that it is impossible to deal with them all here at the moment. It will be useful, however, to say something about the third, that is the future wage of the semi-skilled women in industry.

The report we have already mentioned concerns itself very largely with the question of the wages of women. It states that before the war the average wage of employed women was in the neighbourhood of 12*s.* a week. The independent averages of the most varied trades approached this figure very closely, and the figure was also approximated to by the average woman's wage in both France and Germany. In the metal trades, with which we are most directly concerned, the average was 12*s.* 2*d.* At that time the average woman's wage was somewhat less than one-half the average man's wage. The report further estimates that towards the end of the war the average woman's wages was nearer 35*s.* than 30*s.*, and was rather more than two-thirds of the average man's wage. The wages of women would thus appear to have advanced not only absolutely but relatively. It is very possible that in pre-war days the relation between the wages of men and women was unfair to the women, owing to the fact that they were practically without organisation, and it is pertinent to note that in the textile trades in which they are well organised, woman's wages were nearer 15*s.* a week than 12*s.* Women's wages throughout, in common with men's wages, had shown a tendency to rise for many years before the war, but there is nothing to show that the sudden relative improvement in the woman's position as compared with the man's could have taken place in normal times. The present women's level has largely been reached as a direct result of Government action, and as manufacturers have been reimbursed to cover losses they would have made as a consequence of the rises which have been continually given, they have been comparatively indifferent to the matter. If the women's rate has, as a result of this class of operation, reached a level which, as compared with a man's rate is economically unsound, then that rate either cannot be maintained, or if it is women will be discharged from industry to the maximum extent which it proves feasible to replace them with men.

It is impossible directly to answer the question whether the services of the average woman in industry is worth two-thirds of the services of the average man, but it is interesting to note that the proportion of about one-half which operated in 1914, and which had grown up naturally without outside interference, persisted over a very long period and in many countries. Speculation on the reason for this 50 per cent. wage is, however, bound to be of a somewhat academic nature and need not detain us here. What is more important is to consider if the present 66 per cent. represents a fair proportion under modern conditions. In other words is the average women in industry now overpaid, or underpaid, as compared with the average man. In view of the work which women have done during the war it is a somewhat ungracious task to consider the deficiencies of women as compared with men from an industrial point of view, but no ultimate advantage can come either to industry, or to the women themselves, by failing to take note of the facts of the situation. In connection with the preparation of the report, already mentioned, a large amount of data was collected and a large number of employers were examined bearing on the question of the efficiency of their female employees from an industrial point of view, and throughout it was found that women were worse time-keepers than men. For instance, a large firm reporting through the Engineering and National Employers' Federation stated that women's lost time was 7·1 per cent. as compared with 3·4 per cent. for men. The Tramways and Light Railways Association, and other bodies concerned with the same class of service, stated that one of the defects of the women was "unreliability in reporting for work." In the case of the Post Office the difference between male and female wages was justified among other reasons by the woman's additional sick leave. Other quotations could be made, but it is unnecessary to multiply instances.

There are, of course, physiological reasons for expecting that women would be worse time-keepers than men, and unquestionably in many cases domestic ties affecting women only, or mainly, also work in the same direction. In a sense these things may be "unfair" from a woman's point of view, but they exist and from an economic point of view must be allowed for. The effect of this inferior time-keeping is to decrease the value of women in industry, or relatively to increase the cost of employing them, which is the same thing.

A further matter relatively increasing the cost of female labour from the employers' point of view, is that it involves increased expenditure on supervision and welfare, while in men's factories the introduction of women involves the provision of separate cloak-room and other accommodation, with attendant charges. This latter item may be of importance in the engineering trades from many branches of which women were in the past entirely absent. Apart from questions of time-keeping, or extraneous charges, the matter of the employment of women is closely bound up with their relative industrial ability as compared with men. This naturally varies with the industry concerned and the type of work. In some of the textile trades women are practically equal to men, although in weaving—peculiarly a woman's trade—the women usually make less money than the men because they cannot keep so many looms running. Concerning ourselves more particularly, however, with what is usually regarded as men's work, it is found, again to quote the report, that on sheet-metal work women are better than men, on light repetition work they are equal, on aircraft wood-work they are equal, and on shells they are inferior, both in output and quality. No details are given, but we presume the sheet-metal work referred to is repetition work. It is further reported, however, that women are more costly than men on account of tuition, setting-up and extra scrap. One large firm estimates the extra cost at 30 per cent.

We need not pursue this aspect of the subject further, but before passing on may mention, as of direct interest to engineers, that in transport women have apparently not proved very satisfactory. A much greater number of employees was necessary for the same work than when men were employed. Thus even in carriage cleaning nearly three-quarters as many again of women was required as of men. It was further found that in mixed gangs the men tended to fall to the same output as that of the women they were working with. On tramways and omnibuses women were reported to be slack in collecting fares, to have more "shorts," to be less efficient than men in making up bills or reports, and to be less courteous to passengers. The operating manager of the London General Omnibus Company produced figures to show that the women conductors were costing the company more than half as much as their wages in loss of takings. We confess that this evidence, bearing on the employment of women, and of which we have quoted some samples, has come to us rather as a surprise. We would have expected a somewhat better report. As this evidence has come from the people who employ the women, however, and who clearly can have no interest in depreciating a class of labour which they find satisfactory, it must be accepted. This being so, one is led to speculate on women's position in industry in the future. Unless there is great labour shortage women will not continue to be employed unless they are prepared to work for a wage which is economically sound as compared with the wages paid to men. Economic laws still operate in this country—although some of our present proceedings might lead one to suppose that they have been repealed—and women must be prepared to take the position which their ability and time-keeping dictates.

We do not pretend to be able to sum up this matter quantitively and to say whether the average woman is, or is not, industrially worth two-thirds of the average man. The Committee, whose report we have referred to, find themselves in the same position. They make no quantitive recommendations. What they do recommend, in brief, is that women should receive equal pay for equal work, in the sense that pay should be in proportion to efficient output. To this recommendation no one can object, providing extra expense involved in employing women shall be debited against their output. To fix the scale of equal pay for equal work it is recommended that agreement shall be come to between employers and trades unions acting through Trade Boards or Joint Industrial Councils. This scheme if it proved workable might do much, but the subject is one of such complexity that only long and wide economic experience can ultimately determine the relative industrial value of the man and the woman under the new conditions in which we now find ourselves. We do not overlook the fact that the men's unions will be a very potent factor in any attempt to come to a working decision on this matter, but that branch of the subject is one that we must leave to be dealt with another time.

WORKMANSHIP.

EVERY practical man knows of more than one gradation in workmanship designed to be similar, although it is difficult to define the difference. It is acknowledged that fundamental differences exist, for example, between such ranges of work as agricultural implement and precision tool making, and yet there is a perfectly valid and understood difference. The methods and finish of the one are farcical in the other, though each may be the best of its kind. Precision methods in the making of agricultural implements are quite as reprehensible as in the converse case. There is also well understood divergence between commercial methods, and that of the very best possible, irrespective of cost. Scientific exactitude of the most precise order to the smallest appreciable human error is needed in some instances, and less than the best that human resource allows, or even the very finest yet achieved is still inadequate to the requirements. Dismissing, however, workmanship with such marked characteristics easily realised by the least informed, there remain some considerations relative to workmanship worth discussion.

During the war, work of great refinement was attempted by very diverse concerns whose peace activity differed relatively and absolutely. There were other instances where the refinement needed was less acute, but first rate workmanship imperative. Remarkable results were achieved in unlikely quarters, in others expectation seemed doomed to disappointment, and results on the identical work showed the widest divergence. The fact is that work can be correct to drawing, accurate to textual specification, within the limits fixed; and still be inferior owing to want of that mechanical instinct and reliability which distinguish first-rate production.

Faced with the need for explanation why comparison is odious and trained judgment adverse, it is very difficult to define mechanical shortcoming and argue point by point even when the inferiority is evident. The difference can be appreciated if the two things lie side by side, but even so it needs discriminating intelligence; and where difference of opinion is marked, argument is rather useless to establish even a *primâ facie* case.

Turning elsewhere for illustration, there is the difference between the amateur and professional photographer to go no higher, in one sense both achieve the same result, in another they are worlds apart. The artistic analogy is rather useful; in matters of art generally the outward form and semblance is of less moment than the relative and considerable difference between master and pupil, between original and copy, between superb and second-rate. The distinction to the uninitiated is trivial, even if dimly apprehended; but the well-informed critic has not arrived at his sense of form and ensemble, colour and craftsmanship, without long training and natural ability.

Mechanism and art are traditionally supposed to exist at the opposite ends of a very wide range of human activity, yet all craftsmanship is art, and mechanical art is no exception for all the superior air of the artist as more generally understood. The fact that a piece of mechanism will function

does not make it even tolerably good. Precision as such does not mark the difference, for work may lack exactitude due to its eventual utility; any refinement may be absent, and still the job be workmanlike and fitting.

It takes the craftsman to appreciate, exactly as it takes the art critic to appraise in another connection and for exactly similar reasons. Cultivated sense and true discrimination, are difficult to explain, it would be vain perhaps to give logical reasons therefor; yet, hard as they are to express, they are none the less real and valid. The interlocutor may be dense; life may be too short to educate him, or time be insufficient to give him vision, and after all it might conceivably only lead to his confusion. Those whose business brings them into direct contact with numerous works have some inkling as to the causes which underlie difference—for there are reasons, some easy to diagnose, some more intangible—leading to comparative results commendable or deplorable in connection with mechanism.

It is certain that in a former generation with more limited resources, under conditions vastly more crude, work of superlative merit was produced. It is equally certain that much work of to-day is in all respects superior to past practice, due to the development of modern resources. The matter is not altogether one of method, the work done under modern productive methods, sectionalised and specialised, does differ greatly in results. Comparison in ordinary times is less easy because product differs, but war production, by reason of its widespread and identical character, did allow direct comparison with rather startling effects. It is curious, but true, that in almost every line, one maker's job is superior; due, it may be, to care in detail, more exacting supervision, better local labour tradition, or, perhaps, more nearly to the personal direction, superior organisation and staff which give the internal goodwill and reputation reflected by reliability and beauty of product.

Another matter perhaps less realised, is that in mechanism as in art the common atmosphere contributes greatly. The perfection to which the modern automobile has arrived is largely due to severe competition and a very discriminating *clientele*. From this intensive evolution the aeroplane became practicable. The general interest taken in the motor car, the large number of firms continuously striving after distinction, and the very general publicity, have all had their share in its present phase of development.

Good craftsmanship has a vast industrial and national value. Without an atmosphere of appreciation even the roughest job tends to get rougher and competitive power is lessened in direct ratio. It is largely because of the more general appreciation of mechanical art that it now holds the proud position as the premier activity of the age. Not merely did Watt start an industrial revolution, he began a renaissance of mechanism. The quality of workmanship is not strained, even superficial finish does not deceive. The nearly extinct trade of brass finishing condemned itself by its very name, it combined high polish and inferior workmanship; to-day, insistence is less on mere polish and more upon utility.

Doubtless the educative influences of war conditions have in certain directions raised the standard of appreciation; just as in others war production has had its pernicious effects in the matter of workmanship for acceptance under the duress of circumstance is likely to become refusal where need is less pressing. Possibly the greatest influence toward superiority of product is a continuous attempt to achieve it owing to the co-operative effort of all hands along right lines. Certainly this cultivation which is within the compass of every unit in mechanical production does bring its due reward. It need not involve exhorbitant cost, indeed production may be cheapened; up to a point repetition, by its need for detail appreciation, tends to raise quality even if at the same time it allows a certain inattention having an effect later on.

There was a time when legitimate pride was evident in the very attitude of every mechanic worth the name, and although handicraft is out of date, the preservation of its spirit is important. It is, moreover very evident, that cutting price and quality simultaneously is suicidal, it forfeits reputation, and initial expenditure is only one factor, and may conceivably be the least operative in selection. It is true primitive handicraft has passed beyond recall, but the need for fine workmanship, good design, fitting finish, and first-class product, is still great. Workmanship was benefited in many ways when it ceased to depend upon muscle, and especially in mechanical connections enlisted more and more the aid of the machine. For all that, unless the spirit of craftmanship survives, mechanical art is doomed; bound in chains to simple economics, it will be cheapened out of knowledge in ill-informed hands. Especially is attention to workmanship worth while in Great Britain, for her past industrial supremacy has been achieved upon superiority of product which is not of necessity expensive in a relative sense.

Complex organisation is apt to overlook appreciation and the need for standards of workmanship, although at the same time it affords unique opportunities for the cultivation of the necessary spirit. Direction blames its productive human material, which in turn blames direction, and often the only real critic to be found is a disconsolate foreman bred under different conditions who laments the present without suggesting a remedy. The tone of a shop and the spirit which animates it are the result of mutual interaction, and appreciation of good work costs so little and is so powerful an incentive that its neglect is the more unpardonable.

Perchance the real issue was never more exactly expressed than in a phrase, famous enough itself, used in a connection quite apart from industrialism, "The little less and how much it is, the little more and what worlds away."

THE LATE LORD RAYLEIGH, P.C., O.M., F.R.S.

WHEN Lord Kelvin passed away in 1907, Lord Rayleigh indisputably became the doyen of British physical science and a leader in physical science generally. Possessing little of the enthusiasm of Kelvin, Rayleigh was regarded as the impartial, cautious, critical guide whose experimental accuracy was undoubted, and upon whose judgment, not expressed until after mature examination, one might safely rely as to theory and facts established. Both Kelvin and Rayleigh were professors of physics and natural philosophy, eminent alike in mathematical analysis and fertility of experimental research. Both enriched almost the whole domain of physics by their work. That Lord Rayleigh kept philosophical speculations out of his writings, may have been a question of temperament. If Kelvin had a preference for electrical problems, Rayleigh had his in acoustics and optics. The technical and commercial development of his researches, so important to Kelvin, did not appeal to Rayleigh. Hardly because he was born heir to a Peer of the Realm and was himself a Peer when appointed professor of physics in Cambridge, nor because he underrated the value of applied science. The words in which Rayleigh, as President of the British Association in 1884, referred to the "loss which mankind had suffered" by the death of his predecessor of 1882, Sir William Siemens, and to the motto of Siemens, "Practice with science," would sufficiently characterise his standpoint. That presidential address, in which he reviewed the progress of physical science, could not be called brilliant, and brilliancy never marked his numerous contributions to science, fortunately. Though closely related to two British Prime Ministers and a Privy Councillor since 1905, Lord Rayleigh did not take any active part in public affairs. Thus the popular press scarcely knew the man or the scientist, in spite of his numerous papers and the excellent lectures delivered at the Royal Institution, with which he was connected for many years. His authority among scientists stood all the higher.

John William Strutt, third Baron Rayleigh, was born on November 12, 1842, at Langford Green, Essex, as eldest son of the second Baron, whose title he inherited in 1873, and of Clara, daughter of Captain Vicars, R.E.; the Barony was created in the coronation year of George IV, 1821. He was educated at Trinity College, Cambridge, was senior wrangler and Smith prizeman of 1865, and was elected to the Ward fellowship of his College in 1866. Having been a Fellow of the Royal Society since 1873, he succeeded his former tutor, Clerk Maxwell, as Cavendish professor of experimental physics, resigning in 1884. A casual remark which he made later during a discussion on the teaching of science may perhaps be quoted: "Professorships would be nice, if it were not for the students." The appointment which he afterwards held, in succession to Tyndall, from 1887 to 1905, as professor of natural philosophy so the Royal Institution, left him more leisure for research of his own choice. The other offices he filled, namely, Secretary of the Royal Society 1887 to 1896, Scientific Adviser to Trinity House since 1896, and Lord Lieutenant of Essex, 1892 to 1901, were of a different kind. He was also President of the Royal Society, following Huggins and Kelvin, from 1905 to 1908, when he was elected Chancellor of Cambridge University in succession to the Duke of Devonshire. He was also one of the original Knights of the Order of Merit. The Nobel prize was awarded to him in 1904. He held the Copley Medal, was a Knight of the Prussian Order Pour le Mérite and of the Légion d'Honneur, and, as already mentioned, was made a member of the Privy Council in 1905. He presided, in 1908, over the International Conference on Electrical Units and Standards,* not infrequently intervening to guide the involved and protracted discussions. His presidency had been a matter of course, and it followed naturally that he was asked to become chairman of the committee charged with experiments on the Weston normal cell, and with paving the way for the establishment of an International Commission on Electric Standards. Lord Rayleigh resided at Terling Place, Witham, Essex, and did much of his work there in his laboratory. He married first Evelyn, daughter of Mr. James M. Balfour, of Whittinghame, and sister of Mr. A. J. Balfour, and then Blanche, daughter of the Marquis of Salisbury.

A writer of papers rather than of books, Rayleigh practically left only one book, his "Theory of Sound," two volumes each of about 500 pages, which saw two editions in 1877 and 1894. He also edited, with corrections and additions, in 1870 and 1894, Maxwell's "Theory of Heat," and was joint author with Sir W. Ramsay of a book on "Argon." His other big publication, the five volumes of "Scientific Papers," is what it professes to be, a collection of his reprinted papers, chronologically arranged, mostly without any alterations or comments. The first volume of 1899, covering the period 1869 to 1883, appeared without preface; the second volume opened with a brief preface; the fourth, of 1905, bringing the papers up to 1901, contains an index of names and a classification of subjects; the fifth volume of 1912, deals in articles 273 to 349—a few articles comprise more than one paper—with the period 1902-10. As the treatment is mostly mathematical and the significance of a conclusion is indicated rather than dwelt upon, the classification just mentioned into mathematics, general mechanics, elastic solids, capillarity, hydrodynamics, sound, thermodynamics, properties of gases, &c., does not greatly facilitate the search for a particular investigation; analogies between optics and sound may be found under almost any heading. This collection of "Scientific Papers" by no means exhausts Rayleigh's contributions to science. He continued to present many papers to the Royal Society or to contribute them to *The Philosophical Magazine*, which has published most of his papers; in his early years he had been a frequent contributor to other learned societies and journals, rarely, however, to foreign publications, though he paid close attention to science progress abroad. Though he generally used the simplest apparatus, largely of his own construction, the almost orthodox belief in the extreme accuracy of his experimental determinations was by no means confined to this country.

In his preface to the "Theory of Sound," the first complete English work on the subject, Rayleigh pointed out that this theory to a great extent

* See ENGINEERING, vol. lxxxvi, page 519 and 553.

covered the theory of wave-motion, and one might say that he approached most of his problems from that standpoint. The phenomena of vibrating bars, plates and membranes, of the motion of fluids and gases, of sound, light and electricity, all come under this heading, and it is for that reason, that the classification to which we referred could not but be difficult. A paper on the diffraction of light may concern acoustics as much almost as the title subject. Thermal phenomena interested him chiefly from the radiation standpoint, and we remember only one paper of his on heat conduction (1911). He was always resuming former studies. Going back in 1906 to his investigations in 1873 of membranes and gases in his study of the vibrations by collisions of elastic solids and the impact of elongated bodies and spheres after St. Vénant, Voigt and Hertz, he points out that Hertz's theory of collisions has a much wider application than assumed, and he especially deals with the tendency of waves to alter their form and the problem of the pressure which gases enact on the piston of the confining cylinder, the virtual theorem of Clausius. In discussing, in 1916, the discharge of gases through nozzles into a vessel at lower pressure he suggested an apparatus for testing whether reduction of the pressure in the receiving vessel would really affect the rate of discharge. The pressure due to the collapse of gas bubbles, a problem of interest in connection with the cavitation behind propellers, he investigated in 1917.

There are a great many papers on fluids and hydrodynamics, on vortices, tidal waves, bores, viscous fluids and the motion of solids through them, viscosity, capillary forces, &c. Vortices he studied also in connection with Mrs. Ayrton's experiments on stationary waves. Later, in 1916, he showed that the phenomena are somewhat analogous to those of an elastic cylindrical rod under longitudinal compression, or of a cylinder of fluid disintegrating under the operation of capillary forces. His studies of the dynamics of a revolving fluid (1917) had a special bearing on cyclones and meteorological phenomena and were taken up by Sir Napier Shaw. A paper on periodic irratational waves on the surface of water may further be mentioned in this place. In the peculiar convection currents observed by Benard in 1900 in a thin liquid layer (1 mm. thick) floating on a uniformly-heated plate, he had previously detected periodicities of a second or two with alcohol, and periodicities of several minutes with heavy oils; the currents break up the layer into polygons. As regards capillary forces, Rayleigh calculated that a surface film of oil, $0{\cdot}6 \times 10^{-7}$ cm. in thickness would stop the peculiar movements, due to surface tension, of a piece of camphor floating on water. Inquiring into the stability of the Earth he concluded that the cohesional pressures in the interior of a drop of water would not be insignificant compared to the gravitation pressure inside the Earth.

That the formulæ for the propagation of sound strictly held only for infinitesimal waves, and that finite waves at high speeds would tend to become discontinuous had engaged the attention of several scientists. Resuming this research in 1910 with respect to the discontinuity (bore) in front of a flying bullet, Rayleigh observed that photographs showed a discontinuity layer of appreciable thickness instead of the theoretical microscopic layer, and he concluded that the changes in pressure, density and temperature occurred in two stages, there being an abrupt and a gradual change. He did not solve the problem, however, to which we referred in a recent article on fog signals and on the propagation of sound from sirens, and the velocity of propagation of sound in the atmosphere remains, in fact, only approximately known, whilst its determination for gases (in the laboratory) is exact.

In the theory of Helmholtz resonators he modified the views of Helmholtz slightly. In his work on audition he also followed Helmholtz, pointing out that some of Helmholtz's critics did not seem to be aware how fundamental their objections to certain features really were. The ear, Rayleigh found, could not hear a bird's call of more than 10,000 vibrations per second, whilst a tuning-fork responded to 20,000, and a flame to 50,000 vibrations. The minimum rarefaction and condensation in a progressive air-wave, capable of impressing the ear, he estimated from tuning-fork experiments at 6, $4{\cdot}6$, $4{\cdot}6 \times 10^{-9}$ atmosphere for 256, 384, 511 vibrations; these values were larger and varied less with frequency than those M. Wien obtained by the telephone method. The minimum amplitude of displacement just audible sounds he estimated at $0{\cdot}13 \times 10^{-8}$ cm., that of whistle sounds of frequency 2,730 at 8×10^{-8} cm.; the minimum current recorded by a telephone was $8{\cdot}3 \times 10^{-7}$ ampère, the corresponding amplitude of vibration being $6{\cdot}8 \times 10^{-8}$ cm. His audiphone consisted of a small battery, a microphone and a telephone circuit. As regards the perception of sound direction he considered that a man could distinguish right and left without moving his head, but that as to sounds from front or back he had no means of distinction, at any rate not for pure notes. In the case of high-pitch notes the intensities of the notes in the right and left ear would be different; that would not hold for waves several feet in length, however, and the ear seemed really to be guided not by the intensity, but by perceiving phase differences, judging the sound to come from the side on which the phase was in advance. Further papers on new views as to perception of sound and on the theory of the double resonator were published by him last winter. We have already referred to his fog-signal experiments. In some of these he made use of a tuning fork for opening and closing the ports of the siren, and he observed that this electrically-driven fork would continue to vibrate under the action of the wind alone, not, however, in the manner of a reed, but like an Æolean harp which vibrates in planes at right angles to the wind direction. Among other problems which engaged his attention was that of the whispering gallery in St. Paul's; sound waves, he concluded, had a tendency to cling to concave walls.

Glancing through his optical papers we notice again many happy analogies, and that many of the problems, which are hotly contested at the present time, really go back a good many years. Thus he showed that white light is produced by irregular pulses, not by the superposition of regular trains of waves. The refracting prism impresses a wave-motion on the aperiodic disturbances for all types of disturbances which are slow compared with the period of natural molecular relaxation of the medium; the waves produced might be illustrated by the minute waves which a small obstacle calls forth in a streaming fluid, or by the waves which are set up, when a fishing line is drawn across still water. On the other hand, he demonstrated how to compound white light by the aid of a wooden batten, suspended from the roof of the Royal Institution theatre by four wires (attached to the four corners) and moved longitudinally by a spring; pendulums were suspended from the batten which recorded its own oscillations. The papers on aberration in a dispersive medium concern the distinction between wave velocity V and group velocity U; the two would be different in a dispersive medium. All terrestrial determinations, whether by toothed wheels or by mirrors, determine the U; astronomical aberration was supposed to yield the V, but Ehrenfest questioned that, and Rayleigh (1911) agreed to a certain extent. The five aberrations of Seidel, Rayleigh deduced from Hamilton's principle—neither of the two investigations having been known in the other's country. As regards polarisation and reflection Fresnel's law demands that there should be no reflection at all of light vibrating in the plane of incidence at the Brewsterian angle. Rayleigh found always traces of a remnant reflection (especially with diamond, which never shows complete polarisation), but could not explain certain peculiarities. The cleanest surfaces did not give the smallest reflection, as one would expect, but rather improved with age. Similarly the reflection did not totally vanish when glass was immersed in a liquid of the same refractive index. Fresnel's theory of the grating assumed that a large wave-front remained of large area in spite of changes in phase and amplitude. Rayleigh proved that this is only true as long as the grating interval is small compared to the wave-length, when the recesses act like resonators. His own wave-length measurements were made with Haidinger rings (as in the Fabry and Perot interferometers) due to interference between two absolutely parallel plates, not between surfaces of variable thickness (Newton rings).

It is well known that his name is particularly associated with the problem of the blue light of the sky. Light waves falling upon a mirror are reflected as such in a definite direction, and that holds in cases when the surface of the obstacle which the waves meet is small compared to the wave-length. Small obstacles scatter the light in all directions, and the wavelets generated differ from the incident rays. As early as 1871 Rayleigh showed that the light scattered was the more intense, the shorter the wave-lengths, and that blue light would be scattered more than red light, and he suggested that the sky appears blue because the finest dust particles of the upper atmosphere scatter chiefly blue light. Two years ago, it is interesting to add, Lord Rayleigh's elder son, the Hon. R. J. Strutt, demonstrated that the air molecules could themselves act as scattering particles. Of most direct practical interest are Rayleigh's researches on pinhole photography; on definition and aperture—the definition suffers when the aperture is too small; on inclined telescope lenses for obtaining different magnification in different directions; and on variation of photographic gradation, for instance, by superposing several positives.

Radiation and radiant energy claimed much of his attention. He wrote a historical paper on radiant energy in 1889 and gave one of the three chief formulæ, though not the most widely accepted formula, for the relation between energy and wave-length on the continuous spectrum. The widening of the lines in spectra and its dependence on the motion of the molecules in the line of sight (according to Maxwell's distribution law) and on their cohesions he had studied in 1887. Though he developed the theory of the equipartition of energy, coupled with the names of Maxwell and Boltzmann, he was from the first decidedly sceptic like Kelvin. Reverting to the subject in 1900 he pleaded for some escape from the destructive simplicity of the general conclusion, though it might involve repudiation of some of Maxwell's fundamental postulates. The study of radiative phenomena he left to others. When a paper by his son—who specialises in this field—was discussed some years ago, he humorously declined to express any opinion, though he was "in a certain way responsible for the paper." His comments on J. J. Thomson's constitution of the atom and upon the stability of certain groups of electrons (1906) were critical, and we are not aware that Rayleigh changed his standpoint. The positive charge, he pointed out, was assumed constrained, the negative electrons were to move freely; on that supposition he found difficulty in understanding both the radiations from the atom and the rotation of the electrons in rings, asking how the atom could have the definiteness which the spectroscope demands.

Much of Rayleigh's electrical work was done on units and in connection with British Association Committees. He made an absolute determination of the ohm in 1881, together with A. Schuster; he investigated the advantages and limitations of the condenser and electrometer methods, induction balances, the imperfections of galvanometers, and the electro-chemical equivalent of silver together with Mrs. H. Sedgwick, his sister-in-law; the electrolytic cell of H shape is known as the Rayleigh cell. The phonic-wheel was discovered independently by Paul la Cour (Copenhagen) and by Rayleigh, but not developed by the latter. More mathematical were his later researches on potential problems, the capacity of spheres and cylinders, on the electric vibrations of thin rods (Abraham), on self-induction in thin anchor rings—as to which his earlier calculations, questioned by M. Wien, were confirmed in 1912—and on the effects of junctions on the propagation of Hertzian waves and on the bending of electric waves; the last two papers concerned radio telegraphy.

The exact determination of the density of many gases—not only of those of the atmosphere—and of their compressibility and atomic weight, led to the joint discovery, in 1894, by himself and Sir William Ramsay of argon, the one event which made his name

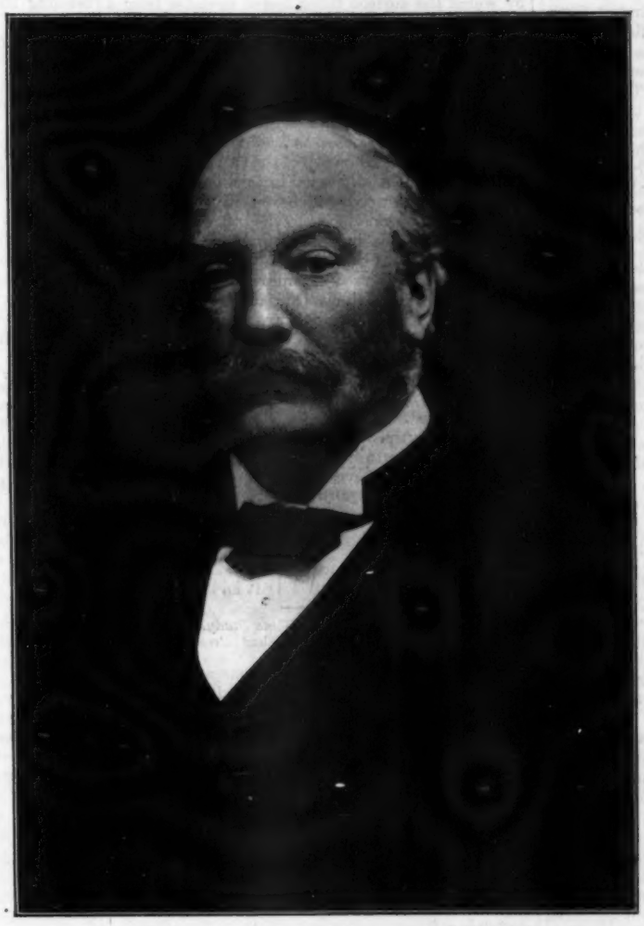
popular for a time. The oxidation of atmospheric nitrogen by the electric discharge he demonstrated to the Chemical Society in 1897, but again he did not follow this problem up. We should not forget to mention one of his early papers on the distillation of binary liquids.

As an interesting exemplification of his experimental methods, we will refer to his notes on breath figures (1911). On a uniformly cleaned surface of glass or metal the breath condenses in drops of the form of small lenses, which meet the glass at an angle that can be deduced from the halo seen when the glass is examined through a candle flame Aitken had noticed in 1893 that, when he passed a blow-pipe jet over the glass and then breathed upon the glass, the track of the flame appeared as a dark line of a very fine film (not drops) of liquid. These marks lasted for weeks, Rayleigh found, and could be silvered. In another familiar experiment of this type a pattern is drawn on glass with the finger (always greasy), and that pattern, though wiped off, reappears when breathed upon. Grease seems to play a part in both these experiments, Rayleigh suggested, and to penetrate into the glass surface, and would thus not be entirely removed by wiping. That consideration might also affect the above-noticed peculiarities of polarisation and reflection, in which both grease and polishing powder have to be reckoned with. Our readers will remember Lord Rayleigh's recent contributions to our own columns, a letter on "The Cutting and Chipping of Glass,"* and an article on "Forced Lubrication."† The theory of lubrication he discussed more fully soon afterwards.‡

Very characteristic were also his remarks on the neglect of the principle of similitude (1915). Physicists, he said, frequently discover new laws which might easily have been predicted. Engineers make use of the principle, but obscure it by their notation. Rayleigh especially referred in these remarks to the way in which gravity is treated. "When a problem depends essentially upon gravity, g makes no appearance; but when gravity does not enter at all, g obtrudes itself conspicuously. Geometrical similarity presupposed, how does the strength of a bridge depend upon the linear dimensions and upon the force of gravity? In order to entail the same strain, the force of gravity must be inversely as the linear dimensions. Under a given gravity, the larger structure is the weaker." Having referred to further exemplifications, Rayleigh emphasised two cautions: There is no prospect of determining a numerical coefficient from the principle of similarity alone (that requires further calculation or experiment), and all the quantities on which the result might reasonably be supposed to depend have clearly to be defined as a preliminary step, though one or more may subsequently be dropped.

These quotations will also indicate that Rayleigh's mathematical mode of expression did not facilitate easy reading. Sometimes he might have made his papers clearer by adding diagrams. One regrets also that he hesitated apparently to draw inferences, and that he did not give to scientists more general critical surveys. For throughout his long period of activity, continued almost to the end, we see him revise and test theories, pointing out to rash theorists what their novel suggestions really imply, correcting accepted or controversial data, and filling up gaps in almost every department of physics and physical chemistry. One of the latest problems which he was unable fully to elucidate last winter, though it is often believed to have fully been explained, was the question why the colours of birds and other animals change with the direction of vision. In an age which has been amazingly productive in bold speculations and novel lines of research, too prone possibly to build upon pebbles and to tear down what seemed to stand on firm rock, he remained the cool critic, competent carefully to weigh and test the evidence, and to decide, not who was right and who wrong, but what might be accepted as established or must be considered as uncertain.

That was also his standpoint with respect to psychical problems and spiritualism. He always had the interest of the scientist in these questions, and he regretted the "provoking attitude of people who might render assistance, who see nothing out of the way in the most marvellous occurrences, or attribute all these things to the devil." He had sometimes pointed out that if they could keep the devil occupied in so comparatively harmless a manner during the long hours of séances, they deserved well of their neighbours. We quote those words—not literally—from his presidential address to the Society of Psychical Research, delivered on April 11 last, a week after the death of Sir William Crookes.



Photograph by Elliott and Fry.

THE LATE LORD RAYLEIGH, O.M., F.R.S.

Lord Rayleigh took a great interest in his large farm and in his labourers, with whom he agreed upon a system of co-partnership; "Lord Rayleigh's Dairies" are well known in London, as his cows are among cattle breeders. For years he was chairman of the Executive Board of the National Physical Laboratory, where he will sorely be missed, and he was constantly consulted, of course, during the war. Though he was most unassuming and not fond of formality, his dignified bearing could not but impress the stranger, and personal regard had a share in the universal veneration he enjoyed. He looked of a strong constitution and attained a ripe age. When he had declined renomination to the presidency of the Royal Society in 1908 and had started on a long journey to South Africa, alarming rumours as to his health reached this country. Those rumours were unfounded, fortunately. But illness came later, and an influenza attack last winter left him very weak. He died on June 30 in his home. Lady Rayleigh survives him. The title passes to his son mentioned above, who is Professor of Physics in the Imperial College of Science, South Kensington. The younger son, Captain A. C. Strutt, R.N., took part in the battle of Jutland. The funeral of Lord Rayleigh is to take place at Terling this afternoon.

* ENGINEERING, February 22, 1917, page 111.
† ENGINEERING, December 14 and 28, 1917, pages 617 and 697.
‡ *Philosophical Magazine*, January and February, 1918.

STEEL WORKS IN NORWAY.—*The Anglo-Norwegian Trade Journal* states that the Minister of Norwegian Industrial Supplies has announced that the Government proposes to subsidise various new steel works and rolling mills planned in Norway. Loans will be granted and premiums given on production. The latest project is a steel works to be established at Eidfjord, Hardanger. A company, with a capital of several million kroners, has secured water power and sites for the works, and will use a new electric melting process which is said to be much cheaper than methods used hitherto. The water power secured amounts to 50,000 h.p., of which 10,000 h.p. will be utilised as a beginning.

NOTES.

OPTICAL GLASS MANUFACTURE.

IN a paper on an "Improved Method of Optical Glass Manufacture," read before the American Ceramic Society at Pittsburgh last February, Mr. George W. Morey, of the Spencer Lens Glass Plant, Hamburg, New York, described his "24-hour" process, which is said practically to halve the time during which the pot is in the furnace and to yield an improved glass, unusually free from bubbles and striae. The chief feature of the process is that stirring is started at an early stage. According to Morey, the pot is, in the ordinary practice, preheated and then set (transferred to the furnace) and heated up to about 1,400 deg. C., to be filled with batch mixed with cullet in several instalments; the fill being complete, the pot is left undisturbed at high temperature for several hours, and stirring begins after the fining period; the stirring is first by hand, and intermittent, for 15 minutes at the time every 2 hours, and mainly intended to remove bubbles adhering to the pot side and bottom. Then follows machine stirring, with the fire shut off, until the pot is removed from the furnace, in which it stays for two or three days. When, as usually, the empty pot is preheated in a pot arch and finally cooled in subsidiary parts, a melting furnace will yield one pot of glass every two days; but the practice varies. Morey now commences to stir during the filling operation. The melting of the batch takes place from the top downward; the upper layer sinters together, the more easily fusible components trickle down, leaving the upper layers rich in silica and empoverished in flux. The fluxes especially of lead compounds settle at the bottom as can be proved by plunging an iron rod into the pot and quickly withdrawing it. This settlement becomes noticeable during the hand-stirring when a dark layer is brought up. The melting is hence slow, the glass mixture is not homogeneous, and the bottom suffers from excessive attack. To remedy these defects, Morey begins with stirring as soon as the pot is a little more than half full and the rod can be floated, and he stirs after the addition of each new batch. In the case of a flint of density 1.617, *e.g.*, run at 1,390 deg. C., fills were made at intervals of 2 hours, the first fill being about one-third of the total batch; the pot, 26 in. high, 28 in. diameter, was heaped up with batch on each subsequent fill. The stirring was first by hand; after 10 hours the stirring machine was put on and run at a good speed, both in circular and vertical motion; 6 hours later the glass seemed to be free from bubbles, the fire was turned off, and the melt was out of the pot in 24 hours. In another case hand-stirring commenced 4 hours after adding the cullet while filling the pot with batch, and the operation was repeated after 5½ hours and 7 hours; after 7½ hours the machine was turned on, and after 15 hours the gas was cut off. The point is then that hand-stirring is resorted to during filling, and that machine-stirring follows until the bubbles have disappeared. Morey became aware in the course of his work that stirring during the filling operation had previously been tried; when he communicated details of his process to the Military Optical Glass Section of the War Industries Board, the Board passed the communication on to other glass manufacturers. As Morey does not speak of any particular method of stirring, the novelty would appear to be restricted to the general change of practice. He mentioned in his paper that some 350 pots had been made by the shorter schedule, comprising all types of glass, flints, crown, baryta glasses, &c., and the 24-hour process had in all cases given a better glass than before.

TESTING MEASURING-GAUGE BLOCKS.

The Pratt and Whitney Company, of Hartford, Conn., U.S.A., are now manufacturing a series of extremely accurate gauge blocks by a process patented by Mr. W. E. Hoke, of St. Louis. These gauge blocks, which are made of a special steel alloy rendered glass hard by heat treatment, are about 1 in. square with a ¼-in. countersunk hole through the centre so that they can be conveniently stacked on a ¼-in. rod, and the thickness is claimed to be accurate within limits of three millionths of an inch. Most of them, it is stated, actually vary by less than one-millionth of an inch in flatness and parallelism of the two surfaces. Naturally no ordinary workshop method can be used for determining errors of this order of magnitude. The method employed, however, is an extremely simple optical one suggested for the purpose by Mr. C. G. Peters, of the United States Bureau of Standards, and it is illustrated and described in a recent issue of *The Iron Age*. To check the flatness of one of the surfaces of the gauge block it is compared with that of a flat disc of optically worked glass by resting the glass disc on top of the gauge block and observing the interference bands formed by the light reflected from the two adjacent surfaces. If the surface of the gauge block is perfectly plane the bands will be uniformly straight and parallel, but if not, they will be curved and irregular. By noting the curvature of the bands it is possible to measure the amount by which the surface being tested deviates from a true plane in terms of the wave-length of the light used, which is usually the monochromatic light from a mercury-vapour lamp. To check the thickness of a block and the parallelism of the two surfaces, the block to be tested is placed on a disc of optically-worked glass together with another gauge block which is used as a standard. A second disc of glass is placed on top of the two gauge blocks, and if both are exactly equal in thickness the interference bands formed will be exactly similar and continuous from one block to the other; otherwise the bands will be in different widths and run in different directions over the two blocks. The same optical method is used for measuring the minute errors in the very high-class surface plates produced by the Pratt and Whitney Company, and some idea of the accuracy obtainable may be formed from the consideration that the bending of a band by an amount equal to its width corresponds to a departure from flatness of one-half of the wave-length of the light employed. The wave-length of the green line of the mercury spectrum is 5,461 $\mu\mu$ (= 0·0000215 in.) and, as curvature of the interference bands of one-tenth of the above-mentioned amount can be easily distinguished, errors of the order of one-millionth of an inch can be measured.

LITERATURE.

Magnetism and Electricity for Home Study. By H. E. PENROSE. London: The Wireless Press, Limited, 1918. [Price 5s. net.]

THIS book is designed, and apparently is well calculated, to attract and interest a large number of those who, having little or no acquaintance with the elementary principles underlying the foundations of electricity and magnetism, desire to understand how certain effects are produced and to be able to follow the reasoning from which practical results of the highest importance have been derived. When the object is so clearly useful, it is perhaps undesirable, or ungrateful, to inquire whether the method employed is always judicious or legitimate. In many electrical experiments it is possible to see only the results, and we are no more capable of explaining the cause or the precise machinery at work, than we are to account for the phenomena of gravity. To ascribe electro-magnetic causes to electronic action is justifiable, and we may accept observed facts, but the exact behaviour of the ether and the way in which it operates are uncertain factors, and the introduction of this agent to explain what is obscure is less satisfactory. But as the authors object is in the first place to attract the student, he thinks himself warranted in adopting a plan which may assist the non-mathematical mind over difficulties, and aid the grasping of facts which, presented in another guise, might prove repulsive. On that ground one would forgive the use of analogies, which are possibly impressive, though they may not be exact. But we doubt, for instance, the fitness or the utility of comparing the effects of a charged insulated sphere on an uncharged with the results of tidal action arising from the attraction of the sun and moon.

A feature of the book, to which it is a great pleasure to draw attention, is the employment of simple and inexpensive apparatus to enable the reader to perform himself many instructive experiments. Very considerable ingenuity is exhibited in the choice of appliances, and if the instructions are carefully followed a successful result may be expected which should prove an effective stimulant to the student, who is fighting his way through difficulties without any specially designed apparatus at his command. Indeed, if he has constructed a home-made galvanometer or Wheatstone bridge for himself, he has made a noticeable advance over those who have used only the laboratory-provided instruments.

It is probable that in the near future, when Government restrictions are removed, many amateurs will give attention to wireless telegraphy, and endeavour to provide themselves with apparatus that will at least serve as a receiving station. It would be quite easy to put together an arrangement that would serve this purpose, without comprehending the problems involved or the principles underlying a successful installation. With the aid of the information provided here, however, the student should understand what he is doing and the reasons for the adoption of a particular design that will work. The author does not shirk the difficulties, though the explanation of such subjects as capacity and inductance is not particularly inviting from a popular point of view. The mention of such topics shows that the author penetrates far into his subject. The work is not by any means confined to the description of simple experiments with iron filings or pith balls, of which perhaps we have had more than sufficient. Opportunity is even found for saying something on the theory of dynamo electric machinery, and a general examination shows that the treatment of fundamental principles is thorough and illuminating.

Aeronautics: Third Annual Report of the National Advisory Committee for Aeronautics. Washington: Government Printing Office, 1918.

THE report for the year 1917 of the American Advisory Committee on Aeronautics contrasts in a remarkable way with corresponding contemporaneous publications over here. The American report is a bulky volume with nearly 500 pages of text in addition to a large number of folding plates, whilst the last British report was a mere pamphlet of some 20 small pages, which merely recorded the character of the work on which the committee had been engaged without furnishing any detailed data as to results attained. It will be interesting to note whether the American authorities will, in their next volume follow our example, or whether, regardless of possible advantages to the enemy, they will continue their present policy of freely publishing results. The report is dated in December last and thus deals in part with a period prior to America's entry into the war. One interesting point referred to in the introduction is that in the early part of the year the military and naval authorities complained of the prohibitive prices demanded by manufacturers. An inquiry showed that this was due to royalties, added by each firm in anticipation of infringement suits by owners of alleged basic patents, who were threatening the trade generally. To deal with the situation conferences were arranged between Government officials, patent owners and manufacturers, which resulted in the organisation of a Manufacturers' Aircraft Association, with the object of removing the deadlock and restraint on trade by pooling patents and designs, which, wherever originating, are, it has been agreed, to be open to all members on payment of a small fee. It was feared at first that this agreement might be held illegal under the Anti-Trust Law, which has been put to many queer uses never contemplated by its authors, but the United States Attorney-General has held that the arrangement does not contravene the Act.

One valuable report included in the present volume is devoted to meteorology, and has been prepared by Mr. W. R. Blair, formerly in charge of the Aerological Investigations, United States Weather Bureau, and now a major in the Signal Corps, U.S.R. An interesting incident described in this report is the reeling in of a kite during the onset of a thunderstorm. As the kite was being hauled down the wind changed suddenly and abruptly from E.S.E. to W.N.W. The observer states that the wind did not swing round, but simply reversed its direction.

Another report deals with an experimental research on propellers conducted by Mr. W. M. Durand at the aerodynamic laboratory of the Leland Stanford Junior University. The wind channel here is of the Eiffel type and has a minimum diameter of 5½ ft., which was considered large enough to allow of satisfactory tests being made with 3-ft. propellers. This size of propeller was selected in order to avoid too large a step in passing from the experimental results to the full-sized screws. Full details of the equipment are given in the report, as also of tests made with 48 models. Some of these models had aerofoil sections, being cambered on the driving face, but Mr. Durand reports that the ordinary screw section with a straight driving face proved markedly more efficient. This question of propeller efficiency is, however, an exceedingly complicated one. The actual problem is not to find the screw which under ideal conditions will show the highest efficiency, but given a certain horse-power and a certain R.P.M. to find the screw, which under these stated conditions will be most efficient. A valuable addition to this report is a memorandum on the law of kinematic similitude, which promises to prove of ever-increasing value as time goes on. As matters stand, it is now possible from experiments on pipe friction with water as a fluid, to deduce the resistance of the same pipe when used to supply, say, compressed air.

Report No. 15 is a glossary of aerodynamic terms and will be welcome to many. Presumably slang terms, although in common use by pilots, are excluded, as we find no reference to the "joy stick." Translations of important foreign papers form an important feature in the report. One of these records investigations on the stresses in balloon fabrics, made in Germany, by Haas and Dielzius.

Questions of aeroplane stability dealt with both theoretically and experimentally are discussed in a report by Messrs. Klemin, Warner and Denkinger, of the Massachusetts Institute of Technology. The authors arrive at the conclusion that the angle between the tail and wings of an aeroplane should be much diminished. The tail, they find, contributes 82 per cent. of the total damping moment, which is more than was computed from theoretical considerations.

The results of tests on the lift and drag coefficients of models of six different forms of aerofoil designed by the United States Aviation Section are set forth in an exhaustive report prepared by Messrs. E. S. Gorrell and H. S. Martin. These designs were based upon forms developed either here or in France and may be held to embody the latest experience. The difficulty in designing aerofoil forms is to combine good lift and drag coefficients with sufficient depth to accommodate the wing spars. The models used were made of brass and finished with the greatest precision, the maximum error permitted in the upper surfaces being 1 mil., whilst for the under surfaces the tolerance was 2 mils. Full particulars of the methods of conducting the tests and of the results observed are given in the report. In order to facilitate comparisons between the British, French and American testing stations, it is suggested that standard brass aerofoils of the R.A.F. and Eiffel types should be procured. Tests of these standards made at the different stations would form a check on the accuracy of the wind tunnels and could be used for checking the reliability of the apparatus provided just as standard weights are used for checking balances.

In another report experiments on complete model aeroplanes are described which have been made to determine the resultant forces on each component and the effects on lift, drag and stability. The gyroscopic effect of the propeller is discussed in a report by Mr. A. F. Zahm, whilst Mr. E. B. Wilson contributes a report on the theory of an aeroplane encountering gusts.

An interesting description of the plant installed for testing the performance of the "Liberty" engine is contributed by Mr. H. C. Dickinson. The engines under test are installed in a large chamber of ferro-concrete, the pressure inside of which can be varied at will. A large refrigerator is also provided, so that the temperature inside the chamber is under control, and the conditions can be made to correspond very closely to those met with at high altitudes. Mr. Dickinson also contributes a note on radiator design, describing observations made on radiators of different patterns exposed in wind channels where air velocities up to 90 miles an hour could be produced with the radiator in place. The experiments are still in progress, but certain tentative conclusions are formulated at the end of the report. Of these the most important is that the rate of heat transfer is directly proportional to the velocity of the air provided that the radiator tubes have a length more than eight times the diameter. This rule was found to hold up to air velocities of 60 m.p.h. The pressure required to force the air through the tubes was in nearly all cases proportional to some power of the velocity, but the index had a wide range from 1·5 to 2·5, depending on the construction. When properly designed "indirect" cooling surface, *i.e.*, metal not in direct contact with the water, appears, it is stated, to be good practice.

BOOKS RECEIVED.

University of Illinois Engineering Experiment Station. Bulletin No. 106. *Tests of a Flat Slab Floor of the Western Newspaper Building.* By ARTHUR N. TALBOT and HARRISON F. GONNERMAN. Urbana: Published by the University of Illinois; London: Chapman and Hall, Limited. [Price 20 cents.]

Notes, Problems and Laboratory Exercises in Mechanics, Sound, Light, Therm-mechanics and Hydraulics. By HALSEY DUNWOODY. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 13*s.* 6*d.* net.]

Electric Furnaces in the Iron and Steel Industry. By Dipl.Ing. W. RODENHAUSER, E.E., J. SCHOENAWA and C. H. VOM BAUER. Translated from the original by the latter and now completely re-written. Second Edition. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 16*s.* 6*d.* net.]

A First Course in the Calculus. Part I. *Powers of x.* By WILLIAM P. MILNE, M.A., D.Sc., and G. J. B. WESTCOTT, M.A. London: Bell and Sons, Limited. [Price 3*s.* 6*d.*]

Standard Tables and Equations in Radio-Telegraphy. By BERTRAM HOYLE, M.Sc.Tech., A.M.I.E.E. London: The Wireless Press, Limited. [Price 9*s.* net.]

The Journal of the Institute of Metals. Vol. XX. Edited by G. SHAW SCOTT, M.Sc., Secretary. London: Published by the Institute. [Price 21*s.* net.]

The Year Book of the Scientific and Learned Societies of Great Britain and Ireland. Compiled from Official Sources. London: Charles Griffin and Co., Limited. [Price 9*s.* net.]

Railroad Structures and Estimates. By J. W. OBROCK, Mem.Can.Soc.C.E. Second Edition, fully revised. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited.

"At a Glance." Twelve Conversion Tables for International Values of British, Metric and Russian Weights, Measures, Temperatures and Dates. By J. E. SLACK and A. DOVEY. London: The Technical Publishing Company, Limited. [Price 7*s.* 6*d.* net.]

Department of the Interior, Canada. Annual Report of the Dominion Water Branch for the Fiscal Year ending March 31, 1917. Ottawa: Secretary of the Department.

Practical Trigonometry. By HENRY ADAMS, M.Inst.C.E., M.I.Mech.E. Third Edition, revised and enlarged. London: Sir Isaac Pitman and Sons, Limited. [Price 3*s.* net.]

The Tenants' Emergency Charter under the Rent Restriction Acts. London: Oliver and Boyd. [Price 7*d.*]

T.N.T. Trinitrotoluenes and Mono- and Dinitrotoluenes, their Manufacture and Properties. By G. CARLTON SMITH, B.S. London: Constable and Co., Limited. [Price 8*s.* 6*d.* net.]

The Institution of Gas Engineers. Transactions, 1918. Edited by WALTER T. DUNN, F.C.I.S., Secretary to the Institution. London: E. and F. N. Spon, Limited.

Carburettors, Vapourisers and Distributing Valves used in Internal-Combustion Engines. By EDWARD BUTLER, M.I.Mech.E. Second Edition, revised and enlarged. London: Charles Griffin and Co., Limited. [Price 12*s.* 6*d.* net.]

A Manual of Marine Engineering: Comprising the Design, Construction and Working of Marine Engines. By A. E. SEATON. Eighteenth Edition, thoroughly revised, greatly enlarged, and mostly re-written to date. London: Charles Griffin and Co., Limited. [Price 36*s.* net.]

The Shipping World Year Book. A desk Manual for Trade, Commerce and Navigation, 1919. Edited by EVAN ROWLAND JONES. London: The *Shipping World* Offices. [Price, 15*s.* net, post free.]

Slide Valves and Valve Gearing. By PETER YOUNGSON, B.Sc.(ENG.)LOND. Glasgow: James Munro and Co., Limited. [Price, 15*s.* net.]

Elementary Principles of Reinforced Concrete Construction. By EWART S. ANDREWS, B.Sc.ENG.(LOND.). Second edition revised and enlarged. London: Scott, Greenwood and Son. [Price, 5*s.* net.]

How to Form a Company. By HERBERT W. JORDAN. London: Jordan and Sons, Limited. [Price 1*s.*]

George Westinghouse, His Life and Achievements. By FRANCIS E. LEUPP. London: John Murray. [Price 15*s.* net.]

GAS CYLINDERS.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with much interest the article in your current issue dealing with the above subject, and knowing something of the present situation heartily endorse the views expressed therein.

Seamless cylinders of 100 cub. ft. capacity, made in accordance with trade regulations, which before the war cost 1*l.* 10*s.* each at the present moment cost upwards of 4*l.* each. Advances in labour and material cannot be entirely responsible for this increase in price, which, if maintained, is likely to arrest all development in the compressed gas industry. I am told that cylinder transport conditions are also going from bad to worse, which means a slower turnover of cylinders, so that even to maintain normal supplies, gas compressors are compelled to purchase new cylinders at the present inflated prices, and at a moment when, as you intimate, fresh legislation is threatened, which may render cylinders bought to-day an obsolete type to-morrow.

For this hopeless muddle which is holding up an industry of prime importance to the country the Government alone has to be thanked. They first absorbed practically the whole output of cylinders during the war, and now, when they could advantageously release thousands of them at moderate prices, one hears of immense quantities of Government cylinders stacked in air parks and elsewhere throughout the country, rapidly deteriorating through want of use. There would be cylinders enough and to spare for all immediate and future requirements if only the unemployed Government cylinders were released, but either because it is nobody's business to deal with this matter, or because some wild idea of direct Government trading is in contemplation, a good market is being lost and a promising industry checked through lack of cylinders.

In April last, having been told that the Admiralty was prepared to sell cylinders, I wrote for particulars. After an interval of nearly four weeks, I received the following reply:—

"With reference to your letter of April 11, making inquiries for high-pressure storage cylinders, I have to inform you that no decision has yet been reached as to the disposal of these cylinders, but in the event of these being put up for sale, your desire to tender will not be lost sight of."

This official reluctance to dispose of cylinders is possibly explained by the following remarkable production received by friends of mine in this city, and no doubt by many others throughout the country.

The Ministry of Munitions of War,
Room 384, Whitehall Place,
London, S.W.,
March 3, 1919.

To.....
.....

DEAR SIRS,

Re the Use of Hydrogen Gas in place of Carbide for Scrap Cutting.

We have been approached by the Admiralty to ascertain whether it would be possible to use hydrogen gas supplied for scrap cutting in place of carbide as at present used, in order to keep the hydrogen work going. Of course, during the war the Admiralty could use all the supply of this for their own work, but now have only a limited consumption. I am given to understand that each blowpipe would consume up to 70 cub. ft. per hour depending on the thickness of the material being cut.

I have permission to get in touch with the trade, and would like to know whether you would be prepared to give this hydrogen gas a trial. To me it appears that it would save both time and labour, as this is charged into compressed cylinders, and there would therefore be no loss caused by wastage, &c., as in using block carbide. If you consider this matter favourably, I should be glad to hear from you whether you would be willing to have a supply of this for trial use. If so, I will make arrangements accordingly. If necessary, it will be possible to have an expert from the Admiralty to show the most economic way of using the mixture with oxygen.

Yours faithfully,

Section Director, B.D.I.A.

We have here a clear trading proposition which speaks for itself. Hydrogen factories erected by the Government under conditions which, as you imply, might well be investigated, are to be maintained (and incidentally their staffs) by supplying their product to consumers in Government cylinders to be conveyed no doubt under conditions of precedence on National Railways! It is apparently assumed that carbide manufacturers, acetylene engineers, and even the private hydrogen producers —who have erected hydrogen plant at their own expense during the war and have supplied more gas in that time to the Government than all the national hydrogen factories put together, are to be washed out in the wave of patriotism, which this official proposal is expected to inspire. I imagine, however, that these mere laymen, although justly indignant with this official effusion, will be undismayed by the threat of official competition, for they will long ago have ascertained the relative merits of acetylene and hydrogen in metal cutting and satisfied themselves, as I have, that where scrap metal is concerned, acetylene is in every respect far the better gas.

Is it not time that all this official meddling and muddling was stopped? As the Admiralty, on the admission of the letter I have quoted, has cylinders available for trading purposes, surely the right policy is to sell them without delay to the gas compressor, who will understand how to conduct his own business.

Yours truly,

"HYDROGYL."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with much interest the article on this subject in your issue of the 20th inst. There is no doubt that the remarkable immunity in the past from accident in the commercial filling and handling of cylinders containing gases under high pressure is mainly

due to the efforts put forward by the traders to "play safe." In fact, the result of the investigations by Royal Commission, to which you refer, was to practically confirm in every detail the precautions observed at that time by all reputable dealers in highly-compressed gases. The report of the committee was ultimately published in detail in Blue-book form as a "Summary of Recommendations."

It must, however, be borne in mind that at that time not only was the trade in highly compressed gases more or less just emerging from its infancy, but our knowledge of the behaviour of various classes of steel now in use was also very incomplete. This would account for fixing the permissible carbon as low as 0·25 per cent. Though otherwise ignoring the effect of the presence of small quantities of other elements in the steel, such, for example, as manganese, the specification as adopted also limited the actual Fe present to a minimum of 99 per cent. It thus imposed a maximum limit on all impurities and alloys collectively, but without differentiation.

There seems to be little doubt but that the existing "Blue-book Recommendations" as to the construction of gas cylinders are now somewhat out of date and require modernising. This can be done without in any way interfering with those who are at present legitimately engaged in the trade, and at the same time will afford additional protection to the public. Precautions will still have to be taken to exclude from circulation the hybrid collection of special cylinders to which you refer and which were purchased by the Government under stress of war conditions, for special and particular application during the war, under circumstances in which the risk of personal injury must necessarily to some extent give way to other considerations.

It is more than probable that at the present day the average amount of carbon present in the steel of the ordinary trade gas cylinder is well below the acceptable limit of 0·25 per cent. The reason of this is not far to seek. From the point of view of the steel producer there is not much difficulty in manufacturing ingots containing an average of 0·25 per cent. carbon. Yet, if this is to be the rejection limit, the steel producer is not going to run the risk of having an appreciable proportion of his plates "scrapped" on chemical analysis, due to variation in the composition of the steel in different parts of the ingot. On the other hand, he will produce a steel ingot in which at the position of *maximum* carbon the percentage does not exceed 0·25. In the rest of the ingot the carbon will be below this and the composition of the plates will vary accordingly.

From the manufacturers' point of view, the presence, for example, of manganese in the steel, adds greatly to its ductility and consequently simplifies the drawing process. There is thus a natural temptation to "go the limit" on manganese. With only the carbon and the iron limited there is the possibility of manganese being present to the extent of some 0·80 per cent. While such steel would fulfil all chemical and physical tests as now demanded, in the case of both plates and finished cylinders, it should be recollected that a high manganese steel is very uncertain, if not erratic, in its behaviour and consequently not best suited for making a compressed gas cylinder for high working pressures.

If, therefore, it is proposed to increase the maximum permissible carbon from 0·25 per cent., as at present, in order to raise the elastic limit of the steel—a suggestion with which I am heartily in agreement—I would like to suggest that a maximum limit of, say, 0·6 per cent. be placed at the same time on the amount of manganese permissible.

So much for the chemical composition of the steel. There still remain the physical tests as applied to the finished cylinders.

First and foremost among these physical tests is the "crushing" test, but the present description of this test in the "Summary of Recommendations" is most ambiguous, if not actually misleading. It could readily be made absolutely definite by specifying the contour of the rounded knife-edges to be employed, and the meaning of the term "nearly flat." This latter might be expressed in terms of the thickness of the cylinder walls. In order to remove all possibility of misinterpretation I would suggest that the knife-edges be described as "of wedge-shape, converging at an angle of 55 deg., the point being rounded off with a radius of ¼ in." A definite interpretation might simultaneously be given with advantage to the term "nearly flat," by substituting the words "to a thickness of six times the thickness of the wall of the cylinder, the measurement being made between the outside surfaces of the cylinder walls.

There is no doubt but that a general amendment to the existing "Summary of Recommendations" along the lines I have indicated above would be acceptable to all concerned in the trade, as making for greater uniformity. At the same time the removal of existing ambiguities would tend to nullify the efforts of those who, for reasons of their own and irrespective of all consideration of the public safety, are desirous of introducing what may be termed "freak" cylinders into the trade.

Yours faithfully,

CECIL LIGHTFOOT, A.M.I.C.E.

9, Cornwall Mansions, Regent's Park,
June 26, 1919.

ENGINEERING TRAINING FOR DEMOBILISED OFFICERS.

TO THE EDITOR OF ENGINEERING.

SIR,—Some time ago it was brought to my notice that a well-known electrical engineering firm in this country had formulated and have now put into practice a scheme, whereby a certain number of ex-officers were received and given a thorough training in their works, with a view to eventually being appointed to those positions in the firm for which, during their training, they had shown themselves best fitted.

The officers in question, during the period of their training were paid a substantial salary—applications were even considered and accepted from men with no previous engineering experience.

The scheme would appear to be an eminently sound one and worthy of a wider and more general application by other firms.

The men thus trained would do their utmost for and stand by the firm that has given them a start; moreover, their training can be specialised and given on lines that are most likely to make them efficient and capable members of the firm.

If any structural steel firm, municipal corporation or other bodies connected with civil engineering, have under consideration such a scheme as the above, it would be most beneficial to many men like myself, who, having completed their university training in 1914, joined His Majesty's Forces the same year.

Such men find themselves unable to obtain a post through lack of practical experience, and with their theoretical knowledge somewhat rusty owing to nearly five years army service.

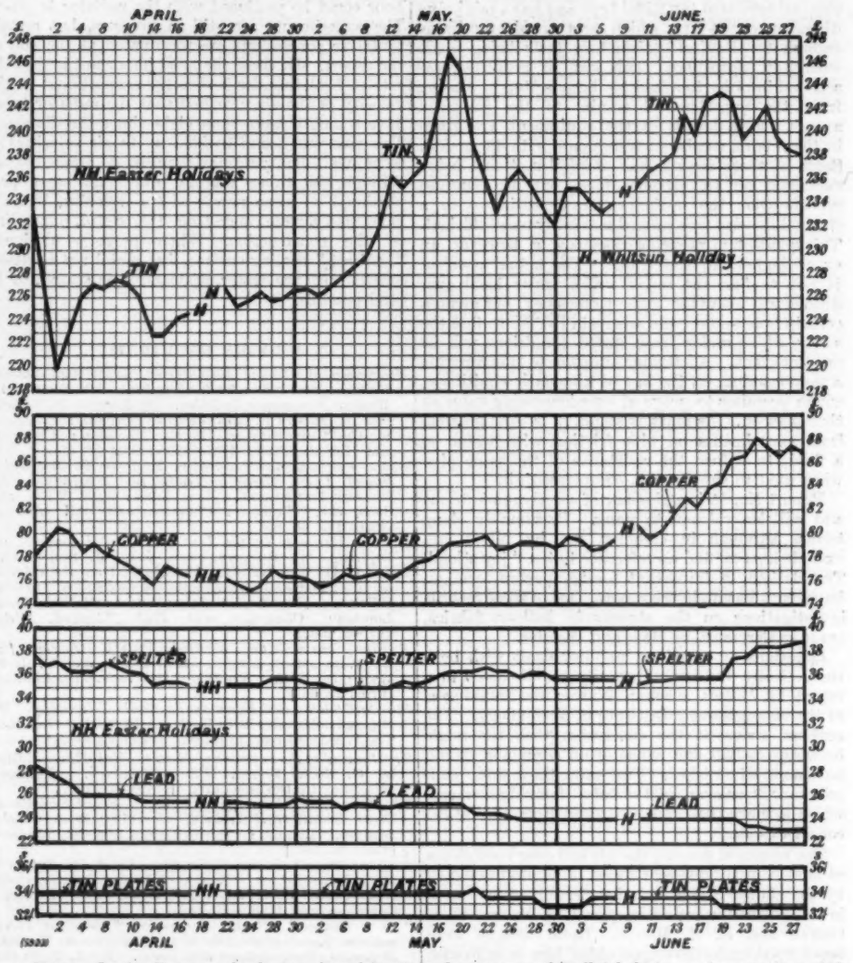
Financial conditions do not allow them to pay a premium and maintain themselves for one or two years without earning any salary, a course which might have been possible before the war, but cannot be followed now owing to other conditions which have arisen. In these circumstances many of them are faced with the necessity of abandoning the career they originally intended to follow in order to take up other work, which, while offering a reasonable remuneration at present, does not possess the ultimate prospects and scope for their abilities that civil engineering would have offered.

I am, Sir, your obedient servant,

"B.Sc."

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1l. each, except in the case of the diagram relating to tin-plates, where they represent 1s. each.

THE RAND GOLD ORE RESERVES.—We read in *The South African Mining and Engineering Journal* that the Rand total payable ore reserves are estimated at 89,905,000 tons, showing a decline of approximately 6,000,000 tons compared with the estimates of a year ago. The journal adds that the Rand being at the caprice of the Government, the agitator and the "coloured gentleman," it cannot venture predictions as to the ultimate dividend value of the reserves in question.

PERSONAL.—Messrs. John Shaw and Sons, Wolverhampton, Limited, tool manufacturers and merchants, state that their representative in Ireland, Mr. J. A. Rutledge, relinquished his appointment with us on June 30, and, with the object of covering the ground more comprehensively, they have appointed Mr. A. A. Kerrison to represent them in the north, and Mr. F. J. Masterson in the south of Ireland. They retain the Dublin Show Rooms at 3A, Burgh Quay; but it is probable that in the future these will be materially developed.—The British Lighting and Ignition Company, Limited, who, during the war, have been established at 204, Tottenham Court-road, London, W. 1, have now removed their head office and works to Birmingham. The new factory, which is a very extensive one, is situated in Cheston-road, Aston, Birmingham, and will in future be known as the B.L.I.C. Works. The London depot and repair works has been established at 201, Tottenham Court-road, and magneto repairs, armature winding, &c., will be dealt with both at that address and the Birmingham factory.—Mr. Allan E. Goodhue has been elected managing director of the Consolidated Pneumatic Tool Company, Limited, a subsidiary of the Chicago Pneumatic Tool Company, with office at 170, Piccadilly, London. The works are at Fraserburg, Scotland. Mr. Goodhue will also have charge of European sales for the Chicago Pneumatic Tool Company.

SOME EXPERIENCES WITH ELECTRIC WELDING IN WARSHIPS.*

By W. H. GARD, C.B., M.V.O., Member.

A GREAT deal has been written about electric welding as applied to ship construction during the past year or so, and some considerable advance has been made in its development both inside and outside the Service. It has been thought desirable, therefore, that some indication should be given to this Institution of the extent to which it has been possible to adopt electric welding in warship construction, and shortly to explain, as the view of the Admiralty officers who have been engaged in investigating the process, what is the scope of its present and possible future usefulness, and the directions in which efforts may justly be made in the attempt to get the most out of it.

Subsequent remarks will assume the use of the coated metal electrode, and it is not intended to discuss varieties of electrodes or other kinds of electric welding, or the apparatus employed, or even the nature of the current used, which could not be done within the scope of a paper such as this; these matters are mainly the concern of the specialist, electrical or metallurgical, and it is known that there are many conflicting opinions in regard to them. Our problem relates to the usual materials employed in the structure of warships and the prospect of combining these materials into a satisfactory seagoing vessel; the question of varying the composition of these materials in order to facilitate their connection by electric welding and improve the quality of the joint has seemed to offer much promise, but nothing can come out of this without the collaboration of the steel maker, and this collaboration must follow further research and experiment as to its necessity and extent.

There is no doubt as to the very considerable advantage to be gained by the use of this process. To a shipbuilder who has seen the endless applications of this kind of connection it is very attractive, and opens out visions of economy and efficiency of which perhaps the best example is the authorisation of Lloyd's of its use in the complete construction of mercantile vessels.

As soon, however, as we come to close quarters with the actual construction of the ship we perceive the necessity for considerable circumspection in the attempt to secure all the advantages which are so evident at the outset. We may with our present knowledge secure some of these advantages, but the big ship built with the minimum of weight, completely watertight or oiltight without caulking, and offering the smallest possible resistance to propulsion is not yet an accomplished fact.

Owing to recent events, useful research, including experience in the application of the process to new construction, has been much retarded, and we have probably learned much less during the time we have been at work with it than we should have done under normal conditions, but this leeway we hope to make up and perhaps some of the more enterprising shipbuilders may be encouraged to follow the lead of Messrs. Cammell Laird and Co., and investigate the process by actual experience in shipbuilding.

Our first intimate acquaintance with this process was by the path of repair work and minor applications, where stresses were small and the method convenient and speedy.

The following example of a repair of this nature will, I think, be admitted by shipbuilders to be a veritable triumph for electric welding: The cast-steel stern-post of a battleship had been damaged to such an extent as to lead at first to the opinion that the work involved in restoring the strength at this vital part was too risky for electric welding, which had, at that time, to our knowledge never been employed for so formidable a task.

On docking the vessel, the main barrel of the stern-post was found to be cracked right through, and in addition about half-way down to the lower pintle the starboard flange was badly cracked, and it looked as though a long period in dock would have to be faced and a new stern-post fitted, but it was decided to attempt a complete repair with electric welding.

The repairs to the flange were quickly carried out, the defective portion was removed, the space carefully filled in and a well-tapered reinforcement was worked on to the original stern-post. The repair to the upper defect was much heavier, as it involved the removal of a large quantity of sound metal to trace and eradicate the cracks and to provide a trough or trench of suitable section to enable efficient welding to be carried out. A reference to the sketches (Figs. 8 to 11, page 26) will show the magnitude of the work, which was skilfully and thoroughly carried out in a very confined space in the heat of summer, in spite of an unfortunate interruption in current which caused surface cracks to develop, and these had to be removed and re-welded before progress could be resumed. Eventually, after a total period of about six weeks, some 6 cwt. of metal had been welded into the stern-post and the repair was finished. As the vessel has seen about twenty-one months' sea service since the work was completed, whatever doubts or misgivings we had as to the suitability of electric welding for this kind of work before taking this one in hand have been dispelled.

Similar jobs of somewhat less importance were also carried out during the war, and a few of these are illustrated by the sketches attached; it is only proposed to briefly describe them now, as, in a measure, the sketches are sufficiently explanatory.

(*a*) Cast-steel stem of a "P" boat very badly broken—five separate pieces were reassembled, welded together and refitted in place with entirely satisfactory results (see Fig. 1, page 26).

(*b*) Shaft bracket of a large 36-knot destroyer broken through—the repairs were carried out in a few hours by Chatham Dockyard (Fig. 2, page 26).

(*c*) Lower portion of stern-post of a Castle liner broken off—new portion was forged and welded into place at Portsmouth Yard (Fig. 3, page 26).

(*d*) Fig. 4, page 26, illustrates a class of work for which electric welding appears eminently suitable; that of reinforcing badly worn shell plating. In this case the yard officers estimated the cost of removal and replacement of the worn plates which were beyond patching at about seven times the cost of reinforcement by electric welding, quite apart from the extra time required in dock for renewing the plates.

(*e*) Renewed portion of shaft bracket of a destroyer which had been worn through the shaft, (Fig. 5, page 26), running direct upon the casting—the worn portion of the boss was reinforced by welding and rebored to its original diameter.

The successful work thus accomplished by this process naturally suggested a much wider field of usefulness in its application to new construction, and an elaborate series of experiments was carried out at Portsmouth in August, 1917, in order to more fully investigate its possibilities, the goal of course being the all-welded ship. Attempts were made to reproduce the conditions in which such welding would have to be carried out in the actual ship, but in this respect it was found very difficult, if not impracticable, to take into consideration all the circumstances which would obtain in new construction. Although we have secured some highly successful test results on specimens produced in the shop for the purpose, subsequent experience has shown that the efficiency of a welded butt in a ship cannot be estimated from the results of tests on small samples. This conclusion is a highly important one, and appears to depend on the fact that the shop conditions will admit of perfect welding if really skilled workers are employed, whereas the conditions in the ship are much less favourable. Our experience goes to show that, as things are, the skill of the welder is the most important factor in the performance, and that if the conditions under which a weld is made are not entirely suitable, reliance cannot be placed on the result. Moreover, we are not yet in a position to state what percentage of efficiency in a weld, where the conditions are as good as possible, may be expected where the work is done at the ship instead of on a shop specimen.

In order to determine whether a welded joint would be affected by sea-water, additional test-pieces were prepared and subjected to corrosion for a period of twelve months, and afterwards tested—the result being shown in Table D, page 28. It will be observed that in only one case, i.e., at a welded lap, was there any appreciable reduction in strength, but it is by no means certain that this effect was due to corrosion, and in view of the other results this particular defect was more probably due to stress not being uniformly divided between the two welds of the lap.

These experiments have been and are still being prosecuted with considerable success at Portsmouth, and the particulars given in Tables A to D show some of the more important results. It will be seen that from the point of view of tensile strength a good welded connection is quite satisfactory, but in ductility, as indicated by the angle obtained in the bending tests, the welded joint falls a long way behind that of the continuous plate. This feature appears to be common to all welded work—as a general rule less success is obtained with plates above ½ in. thick both as regards strength and ductility, but the tables show that excellent results are obtainable with plates up to 1 in. in thickness; and, further, that flat or downward welding is the most easy to carry out, and the results are usually the best with this type of welding. Clearly, then, the application of electric welding to new construction would depend upon the extent to which the details could be designed and arranged to ensure the maximum amount of flat welding at the ship, and elimination as far as practicable of the difficult overhead and horizontal welding.

Incidentally it may be remarked that, by comparing welded joints with riveted joints, the "slip" of a riveted joint under quite moderate stresses was shown up with considerable prominence; and this would seem to suggest that, if our assumptions upon which stress calculations are based are anything like correct, the stresses now accepted for structural work are as high as can be carried with safety, unless some improvement in the efficiency of the connection between the parts of the structure can be obtained by means of electric welding or otherwise.

The tables show but a few of the results of the tests actually carried out, and are merely quoted to support what is now almost universally accepted that specimen welded connections can be produced which are superior to any riveted connection known. In view of what has already been published in this direction it is not thought desirable to make the lists more extensive, as for some time now our efforts have been devoted to the practical application of our present knowledge rather than continuing the investigation of the physical properties of welded joints as compared with those of homogeneous plates or riveted joints. As part of this aspect of the process, welds by all promising electrodes (British) have been tested comparatively at Portsmouth, and it is hoped that opportunity will occur to publish these results, as more extensive sources of supply of reliable electrodes appear to be necessary before electric welding can take up its proper position in general engineering and shipbuilding industries.

These experiments and tests, referred to above, attracted a considerable amount of attention and thought, and representatives of certain prominent shipbuilding firms and Lloyd's Register had the opportunity of seeing them, and in a very short time their value began to show itself in the construction of the Richborough electrically-welded barge, full details of which have already appeared in the press; whilst Lloyd's carried out an independent and important series of tests, and obtained some interesting results as to the effect of fatigue upon welded connections and other particulars, some of which have recently been made public.

A few experiments have been carried out as to the practicability of forging electrically-welded connections. Two test-pieces, 18 in. by 3 in. by ½ in., electrically welded in the centre, were bent hot across the weld; one was satisfactory and the other developed cracks at the extreme angle of bending. Four similar pieces were forged down to 1 in. by ½ in.; no difficulty was experienced or flaws developed during the process. These pieces were raised to cherry-red heat and bent double; three were quite as satisfactory as would be expected from ordinary material and methods, the fourth was not quite so satisfactory. There is, therefore, no indication that electric welding produces a "hot shortness," as had been reported from other sources.

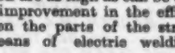
Some two dozen samples of good and inferior welds by varying makers of electrodes have been subjected to microscopical examination, to trace, if possible, the relation between the physical properties and their structure. These were classified according to the nature of their fracture, and the classes were again divided into three groups, viz., fine, medium, and coarse grain, and it was ascertained that the good welds fell indifferently into their classes and their respective subclasses. The same was almost true of the inferior welds, leading to the opinion that the fracture in the latter was due to flaws, *e.g.*, holes, lays, and lack of juncture, and that these experiments revealed no connection between the microstructure and the physical properties of the weld; or, in other words, the skill of the welder was the predominating factor in successful welding, and that such skill might easily obscure many of the variables which collectively affect the physical quality of the weld.

At an early stage in the progress of the experiments referred to, it was decided to weld portions of the bulge structure fitted to one of His Majesty's vessels, and on investigating the question it was thought that there would be no gain in welding any of the non-watertight portions of the work, as it was felt that for cheapness and speed of construction ordinary hand riveting, and in particular hydraulic riveting, was, with our present knowledge of electric welding, the most reliable and efficient, and these views have not been modified by

TABLE A.—ELECTRIC WELDING.

Results obtained at Portsmouth showing roughly the efficiency of butt welds on steel of 26 tons to 30 tons.

Butt welds :—

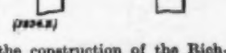


Type of Weld and Thickness of Plate.	Average of Five Tensile Tests.	Average Angle of Four Bending Tests.	Time of Welding 20-in. Length.	Supply Voltage.	Average Arc Voltage.	Average Current.
	tons per sq. in.	degrees.	minutes.			amperes.
¼-in. plate, flat weld	25·3	70	20	110	24·0	70·0
½-in. plate, flat weld	21·53	64½	27	110	24·0	108·0
½-in. plate, horizontal weld* ..	18·81	18	58	110	26·5	100·0
½-in. plate, vertical weld ..	20·01	34½	47	110	27·7	117·5
½-in. plate, overhead weld ..	23·01	52½	63	110	26·5	82·0
¾-in. plate, flat weld	25·53	27½	49	110	27·9	120·0
1-in. plate, flat weld	22·16	17½	69	110	27·9	130·0

* Horizontal welding is difficult and always gives inferior results. This is due to the difficulty in removing slag from between the weld and the upper surface due to the sharp angle between weld and this surface, thus :—

This method should always be avoided if possible; but where essential, better results would certainly be obtained by increasing the angle of the upper surface, the lower plate not being bevelled, thus :—

This was done in the case of stern-post in Fig. 3, page 26.



* Paper read before the Institute of Naval Architects, April 11, 1919.

subsequent experience. Further, the combination of widely spaced rivets and welding, which it was thought necessary to adopt for the watertight portions, did not interfere to any extent with the present practice of overhead welding that was involved. Moreover, it did not afford a striking example of the economy which may be effected in construction when welding and riveting are associated together, since in the portion wholly 75 per cent. to 90 per cent. of the riveting and drilling would be saved according as the connection is compared with the double or treble riveted buttstraps.

The experiments previously referred to clearly show

Fig. 1. STEM. BROKEN IN 4 PLACES AND WELDED TOGETHER. TIME TAKEN FOR WELDING, 7 DAYS.

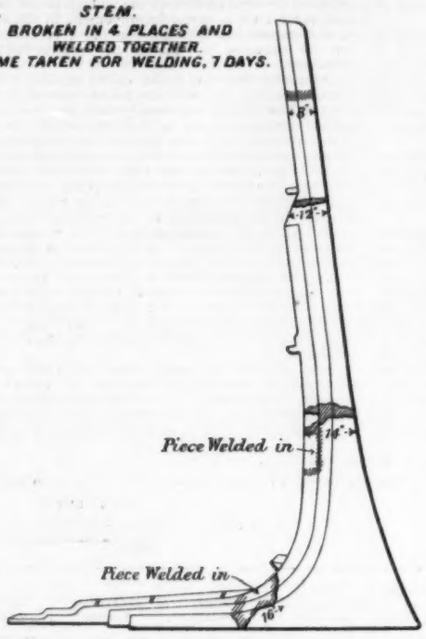


Fig. 3. STERN POST. WORN PINTLES OF POST RE-INFORCED BY WELDING AND RE-BORED. SCALE 3/8" = 1 FOOT.

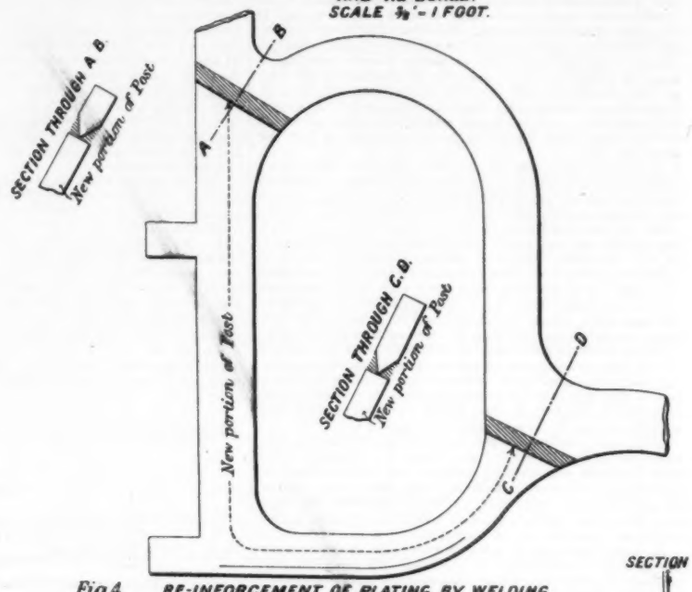


Fig. 2. SHAFT BRACKET. WELDING SHOWN IN 750 FT. OF QUASI-ARC ELECTRODES. USED SIZES N°8 & 10. TIME TAKEN 18 HOURS. SCALE 1/2" = 1 FOOT.

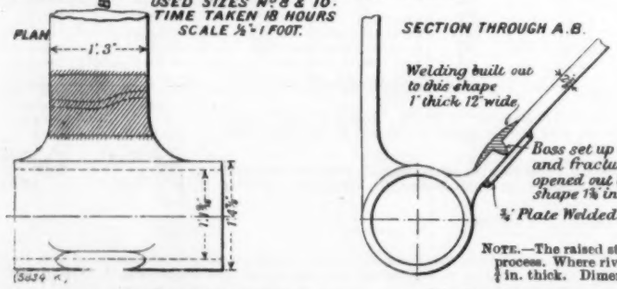
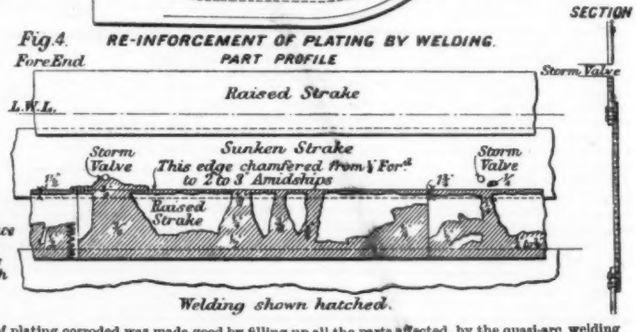

PLAN
1'. 3"
SECTION THROUGH A.B.
Welding built out to this shape 1" thick 12" wide
Boss set up in place and fracture opened out to this shape 1⅛ in width
¾" Plate Welded

Fig. 4. RE-INFORCEMENT OF PLATING BY WELDING.



NOTE.—The raised strake of plating corroded was made good by filling up all the parts affected, by the quasi-arc welding process. Where rivets were affected, they were removed and new ones inserted. Original poundage of plating 30 or ½ in. thick. Dimensions indicate depth of corrosion. Corrosion extended over a length of 115 ft.

Fig. 5. SHAFT BRACKET. SCALE 1/8" = 1 FOOT. ELEVATION.

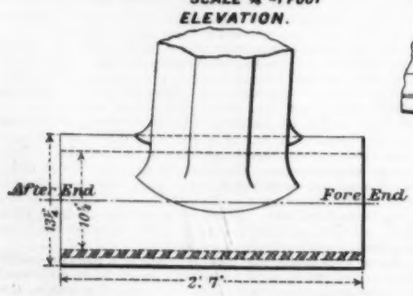


Fig. 8. STERN POST. PART ELEVATION. SCALE 3/8" = 1 FOOT.

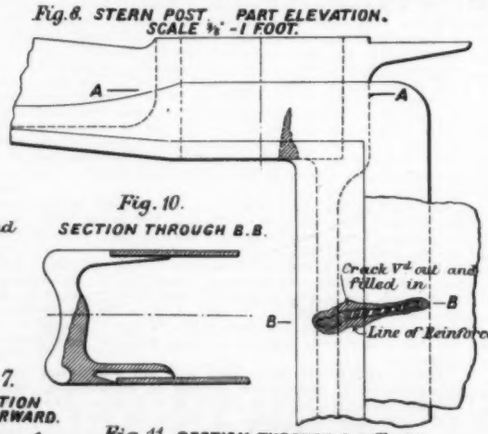


Fig. 9 STERN POST. SCALE 3/8" = 1 FOOT. PART PLAN AT A.A

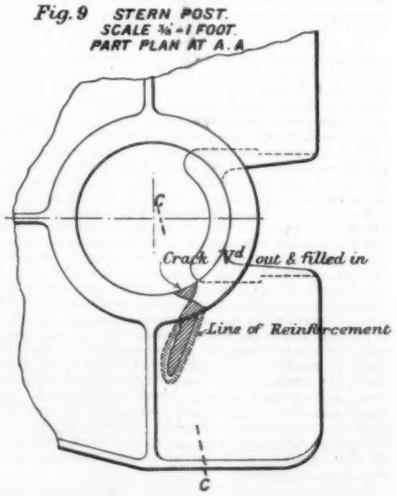


Fig. 10. SECTION THROUGH B.B.

Fig. 6. END ELEVATION LOOKING AFT.

Fig. 7. END ELEVATION LOOKING FORWARD.

Fig. 11. SECTION THROUGH C.C. (Fig. 9.)

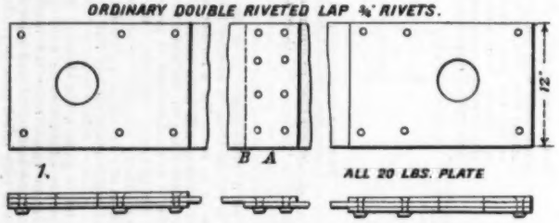
erection and of efficiently closing the work—an important consideration in this case in view of the nature and form of the compartment to be welded, and the necessity for completing the vessel as expeditiously as possible.

The compartment was a section of the bulge 20 ft. in length, which was by no means ideal for an experiment of this nature on account of its angular shape and the riveted both laps and butts were double riveted. In the subsequent vessels fitted with bulges, single riveting at the laps and butts was adopted as shown in the sketch, Fig. 12, page 30. It is pointed out that a lap with a single row of widely-spaced rivets welded on both edges is superior in strength to any riveted connection in common use, and if this connection was used, from that the introduction of widely-spaced rivets had no effect on the strength of the joint, the whole of the strength being derived from the weld. It is clear, then, that these structures would have been equally strong had the riveting been omitted altogether, and the only reason why this was not done was the difficulty of assembling the structure without the use of bolts, as, to

ELECTRIC WELDING IN WARSHIPS; SPECIMENS OF TESTS CONDUCTED AT PORTSMOUTH DOCKYARD.

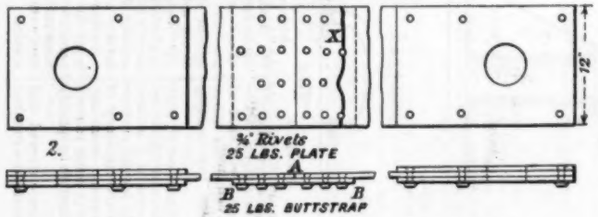
TABLE B.

ORDINARY DOUBLE RIVETED LAP ⅝" RIVETS.



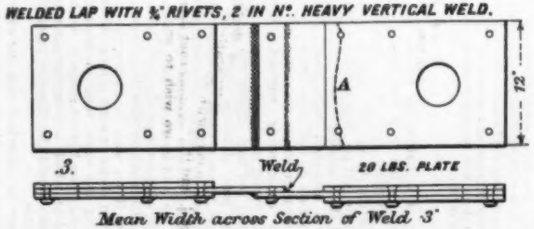
Results of Tests.	
25 tons.	No movement.
30 tons.	Caulk visibly open. No slip.
35 tons.	Caulk visibly open both edges.
40 tons.	Caulk continued to open.
50 tons.	Ditto No slip.
60 tons.	Both caulks open $\frac{1}{16}$". Slip at° A, $\frac{1}{32}$ in.; at B. $\frac{3}{4}$ in.
96 tons.	Break, all rivets sheared.

ORDINARY TREBLE RIVETED BUTT.



20 tons.	Caulk at A visible.
30 tons.	Caulk at A open $\frac{1}{100}$".
40 tons.	Caulk at A open $\frac{1}{100}$".
50 tons.	Caulk at A open $\frac{1}{100}$", and B started.
	Load released.
	Caulk at A closed to $\frac{1}{100}$".
60 tons.	Caulk at A open $\frac{1}{16}$ in.
109 tons.	Break plating through X.
	Caulk A open $\frac{1}{16}$ in.
	Caulk B open $\frac{1}{16}$ in.

WELDED LAP WITH ⅝" RIVETS, 2 IN N°. HEAVY VERTICAL WELD.

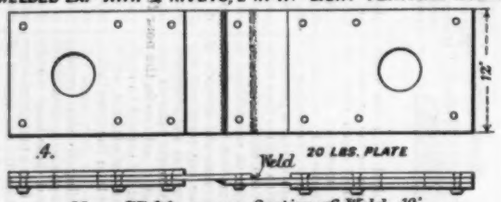


Mean Width across Section of Weld ·3"

Plate broke through A under load 111 tons.

Weld intact at this load.

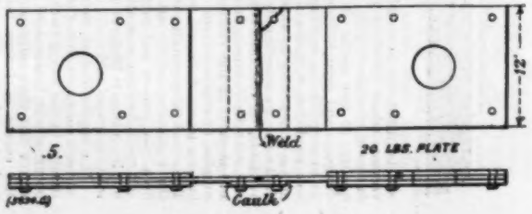
WELDED LAP WITH ⅝" RIVETS, 2 IN N° LIGHT VERTICAL WELD.



Mean Width across Section of Weld ·19"

Weld broke at both edges.
Load 101 tons.

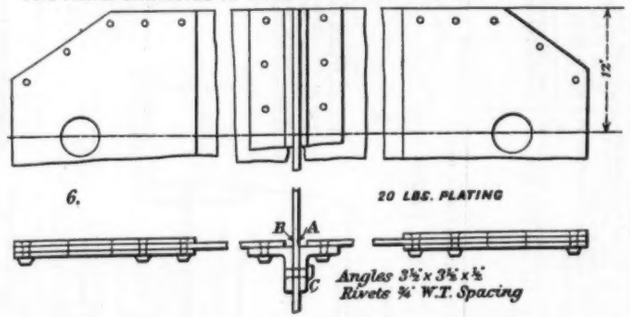
STRAPPED BUTT. BUTT WELDED VERTICALLY.



Load gradually applied.
70 tons. No movement.
117 tons. Plate tore for 4 in. of width and weld for 8 in.

TABLE C.

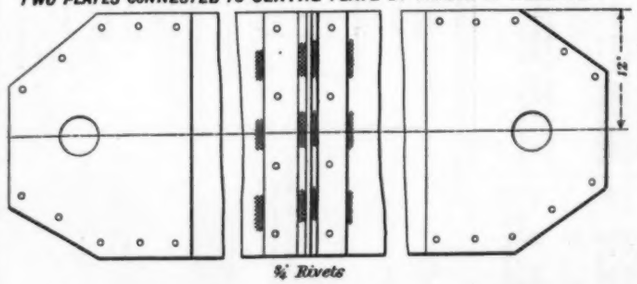
TWO PLATES CONNECTED TO CENTRE PLATE BY ANGLES & RIVETS.



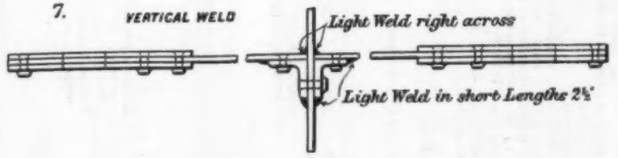
Results of Tests.

Load.	Deflection at A.	Deflection at B.
tons	in.	in.
15	$\frac{1}{1000}$	$\frac{1}{1000}$
20	$\frac{3}{1000}$	$\frac{1}{4}$
30	$\frac{1}{2}$	$\frac{1}{2}$
56	Bars pulled off rivets "C."	

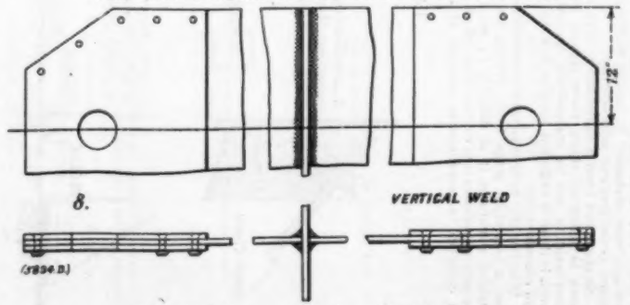
TWO PLATES CONNECTED TO CENTRE PLATE BY RIVETS & WELDING.



20 tons.	No movement.
40 tons.	No movement.
60 tons.	No movement.
74 tons.	Weld at root of one angle broke.



TWO PLATES CONNECTED TO CENTRE PLATE BY WELDING.



Mean Width across Section of Weld ·204".

Welding fractured, causing separation.
Load 106 tons.

ensure satisfactory welding, all joints must be well closed.

The sketch, Fig. 12, page 30, shows the general type of construction adopted and the nature of the welding carried out. It will be seen that the plating was arranged on the clinker system, so as to make the outside weld, which is relied upon for watertightness, a downward weld. The water test showed that this course was justified, as very few leaks developed on test. In a subsequent vessel the raised and sunken system was adopted and the results were not so satisfactory, as the overhead welding involved a much greater strain on the operators; but the difficulties of this type of welding are by no means insuperable, although of course it should be avoided when practicable. It was found that it was comparatively easy to train an operator to make a single run of overhead welding, but a great deal of training was necessary to enable successive runs to be added to the first run satisfactorily.

As there has been a continued growth in this class of work in following ships, there cannot be much doubt that welding can be successfully applied to structural work if there is sufficient time to give the various details full consideration.

Whether this hybrid type of construction merely mark but a transition stage from riveted structures to all-welded structures it is difficult to say, but with our present experience it is certain that before this transition is complete a considerable amount of research work will be necessary to enable us to deal with the many variants which collectively contribute to the success or failure of electric welding, any or all of which affect the quality of the weld. It will be necessary to train designers and draughtsmen so to frame ship structures as to simplify the welding operation by producing the best conditions to make it reliable, to devise a practical means of detecting inferior welds or to ensure that none shall exist, to considerably increase the electrical power available, to overcome the difficulties of assemblage to suit welded structures, to suitably protect both welders and workers in the vicinity, to increase the sources of supplies of electrodes, &c., before we can carry out any large amount of electric welding work at the shipyard. These and other considerations lead to the opinion that the realisation of the all-welded ship will necessarily be a slow process and only attained by careful thought and consideration and attention to details, for which but little time is likely to be available in the near future without special effort.

The application of electric welding to ship repairs and new construction has been accompanied by occasional failures in the Royal Dockyards, and these have mostly occurred with butt-welded joints. It is a matter of some regret that the conditions at the time did not permit of the causes of failure being more fully investigated, and the defect was usually summarily dealt with by riveting on a strap.

Portsmouth reported (*a*) that a riveted butt which had been welded in the 30-lb. keel plate of a light cruiser, broke, with a loud report, under a 2-lb. water test. (*b*) A similar old weld in a "P" boat was found to be cracked in places, the old rivet holes in way of the weld leaking. (*c*) Welded butt in bottom strake of bulge plating of a battleship broke suddenly. This butt was previously riveted. (*d*) Butt in bulge plating of another battleship which had no strap behind cracked after welding.

Several attempts have been made to weld up defective butts and straps in ships' oil tanks without conspicuous success, probably owing to the presence of oil and red lead, whilst the welding caused adjacent rivets to leak, although these were watertight before welding. In these cases the added metal was found so hard as to be almost uncaulkable. After the above experience it was decided not to use lap welding except for comparatively thin plates.

Where with ordinary care we can ensure a sound weld (and it seems evident that it is desirable to avoid the use of rivets if we wish to ensure the success of a welded joint), the rivets in such a joint, if only for the purpose of closing the work, tend to decrease the efficiency of the joint. The hybrid stage of construction previously referred to, which now seems necessary in order to close the work, should therefore be passed through as quickly as possible.

It may be remarked that our experience showed that the resistances and many of the other accessories supplied were but ill adapted for rough usages at the ship, and much more robust fittings are essential if the use of electric welding is to be extended in the shipyard, as we have every reason to believe it should be.

On the experience to date, we have agreed with certain builders to work on lines such as have been pursued at the dockyards as a preliminary to a much greater expansion, and to enable them to acquire a skilled staff of welders, so as to be ready for a further advance by the time electric welding will have taken a more prominent place in contributing to the structural strength of our ships. But it is thought that at present neither our designers, draughtsmen, workers, nor shipyard appliances are sufficiently advanced or educated in the matter to embark on any extensive application of electric welding to naval architecture on any but a very small scale.

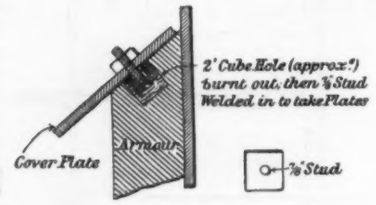
In the appendix is given a list showing the class of work in warships for which electric welding has been permitted in certain cases, after the overseers have been satisfied that the equipment and experience of the firm's staff might be fully relied upon to produce efficient results. This list has no pretence at finality, and any

TABLE D.—CORROSION TESTS.

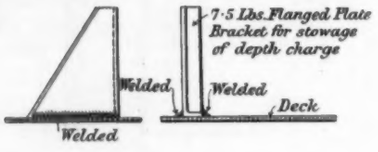
Description.	Specimens Tested Shortly after Welding.	Specimens Uncoated and Exposed to Atmosphere for Four Months, then Suspended between Wind and Tide for Eight Months.	Specimens Coated with One Coat of Protective and One of Anti-fouling Composition, and wholly Immersed in Sea-water Twelve Months.
Welded lap. Lap 2½ in. wide, light vertical weld along each edge similar to (4), Table B.	At 101 tons weld broke and rivets in lap sheared. Mean width across section of weld 1·91 in.	No visible corrosion. Up to 50 tons no movement. At 87 tons weld broke and rivets in lap sheared.* Mean width across section of weld 0·20 in.	Up to 100 tons no movement. At 129 tons weld broke and rivets in lap sheared. Mean width across section of weld 0·23 in.
Welded butt. Butt welded on flat, strapped at back. Edges of strap caulked similar to (5), Table B.	Up to 60 tons no movement. At 117 tons plate broke through line of rivets.	Up to 100 tons no movement. At 144 tons plate and weld broke.	At 139 tons weld broke and rivets in lap sheared.

* This is the result referred to as being less than the original result.

TABLE E.



Welding studs in armour to attach fittings such as davit sockets, &c.



Brackets for depth charge rails and stowage, also other connections to deck.

Welded in order to avoid piercing the deck.

LADDER STEP.

Renewing the ribs on worn steps of mess deck ladders, &c.

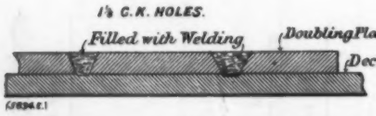
This avoids scrapping the plating.

SKYLIGHT COAMING.

Coamings to skylights increased in depth, old portion with clips, &c.

Already attached, shifted up.

1½ C.K. HOLES.



(7894.c.)

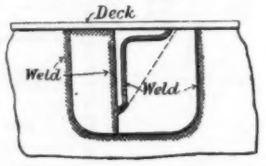
Doubling plates tacked to the deck by means of 1½-in. holes countersunk and filled with welding material.

This avoids piercing the deck.

Disconnecting fittings and structure under the deck and much awkward riveting is saved.

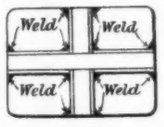
TABLE F.

O.T. BULKHEAD.



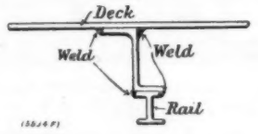
Recess of plate were slotted over the beams and welded in wake of beams also to the bulkhead. This method is very simple compared with the usual process of forging angle collars to fit round the beam.

WATERWAYS TO HATCH COAMINGS.



Waterways to hatch coamings.

Channel bars welded to the coamings at side and to each other at middle.



(5514.P.)

Overhead rails for transporting ammunition were supported from underside of deck by being welded to Z bar hangers and to transverse beams.

After welding they were tested and found satisfactory.

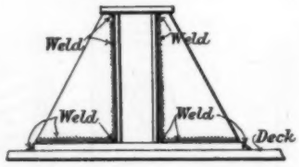
On removing strakes of outer bottom plating it was found that in some cases the plate was cracked in wake of rivet holes, and some of the rivet holes elongated.

The cracks were veed and welded, and the rivet holes filled in by welding and re-drilled as necessary.

Outer bottom plating.

Saving plates in repair work.

DAVIT SOCKET.



Sockets for davits.

Constructed with 3-in. (internal diameter) tube, 7-in. (diameter) flange on top, and 15-in. (diameter) flange on bottom, both welded on three plate brackets, also welded on socket, then welded in place on deck.

FAIRLEAD.

(7894.d.)

Fairleads made totally of plate horns bent, then veed at bottom and welded to base plate.

recommendation for further development will receive every encouragement. In the first place, however, it has been our custom to await proposals from the firms, and no attempt has been made to force the pace, as a failure would lead to a want of confidence in the process which it is desired to avoid if practicable.

It will be seen that so far we only accept electric welding for work of a less important character, or in the case of large castings where the work can be carried out by specially skilled welders. There is, however, a big field for usefully employing electric welding for fittings such as eyeplates, mast hoops, hinges, and many other similar services such as are shown in Tables E to H, and where these fittings are such that the maximum sea-going stresses can be fully represented, either by a practical test or testing machine, and in these cases we would encourage any proposal to use electric welding as a substitute for forging or casting as the case may be.

In this connection it may be interesting to remark that an 18-in. torpedo tube has been electrically welded and tested without showing any sign of weakness or flaws, and that an extension of this process for the purpose is under consideration.

It may be argued by enthusiasts on this subject that we are justified, in view of the labour-saving possibilities of electric welding, in proceeding at a much faster pace in the matter than has been outlined above. To this it may be said that these opinions are based upon a considerable amount of experience, and until the difficulties of erection without angles or rivets, and properly closing work, have been overcome, and a close study has been made of the means to be adopted for proceeding with the work as expeditiously and efficiently as with the customary processes, we hesitate to commit ourselves to accepting welded structural connections in ships which are subjected to high stresses. In short the process has not reached the stage where it can be specified by the naval architect, as full reliance upon the results that may be produced by the average shipyard worker cannot be expected at present. At the time of writing we regard the regulations on this subject which have been issued by Lloyd's for merchant work as inapplicable to warship work, even though considerations of structural strength are probably substantially the same.

I may say that we have investigated this subject to the full extent of the means at our disposal, and have received ready and valuable assistance from experts in the various divisions of labour which bear upon the problem, and especially in connection with the repair of the stern-post of a battleship, shown in Figs. 8 to 11, page 26, are we indebted to the Quasi-Arc Company, who, at a time when our knowledge was lights, gave us the benefit of their scientific experience, and supervised that important job in a way and with a success which met their fullest appreciation.

As a result of the energetic research which is now in progress, we shall probably in course of time be able to obtain improved electrodes on a competitive basis, and it remains for us to devote our most strenuous endeavours to the production of really efficient welders, without whom the best cannot be got out of the process. This is a work of time, and it has been estimated by certain well-qualified authorities that years even are necessary to develop the required degree of proficiency in association with a high standard of intelligence in the workman. The use of the electrode is really an art, and though the analogy may seem to be stretched, the phrase that "artists are born and not made" would probably apply with considerable force to an expert electric welder who, in addition to the other necessary qualifications, requires to have the power of concentration highly developed. It is applicable to many trades, and it follows that an expert in one trade is not necessarily an expert in another, nor is its method of application the same in all. These things need to be borne in mind when discussing the best method of training welders in order to secure the great saving of time and labour which may be anticipated from perfection in the use of this appliance.

In course of time, too, the present conflict of opinion among authorities as to the most appropriate nature and voltage of electric current to be used, the best type of electrode, &c., to secure the nearest approach to perfection, will doubtless be resolved, and we shall reach what may be described as standard conditions for electric welding. If, in addition, we can discover some means of thoroughly closing shipwork without the use of rivets, we shall then be in a position to undertake with confidence the complete construction of a vessel by electric welding. If, as previously indicated, we can secure the co-operation of shipbuilders and others interested, we shall rapidly approach the end we have in view.

APPENDIX.

CLASSES OF WORK IN WARSHIPS FOR WHICH ELECTRIC WELDING HAS BEEN PERMITTED IN CERTAIN CASES.

Reinforcing and repairing castings such as stems, stern-posts, rudder frames, &c., making good pitting in bottom plating, making right-angled or other bends in angle bars, tee bars, &c.

Scuppers and pipes, fresh and salt-water service pipes, bulkhead pieces, &c., oil fuel filling pipes, bulkhead pieces, &c.

Electric fan and motor stools, ammunition bollard hoist seats, pneumatic pump seats.

Air locks, engine-room vent, trunks, ammunition trunks and similar fittings, mushroom vents, ventilation hoods and trunks, supply and exhaust trunks built into hull.

Fresh-water and sanitary tanks, hot-water tanks in wash-places. All lockers of various types, store-room tanks, trough to wash-places.

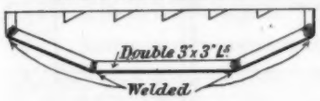
Coamings and covers with all fittings, skylights and covers with all fittings, watertight and oiltight coamings, watertight door frames, foundation strips for corticene panels, foundation bars for engine and boiler bearers to inner bottom plating to avoid piercing oil tanks, collars to frames, deck beams, &c., that pass through watertight decks, bulkheads, &c.

Seamen's head, cooling chambers, shell bays, tubes for returning cases, deck lugs for mess lockers, canopies to hatches, mess-table hangers, legs and stools, small racks for various purposes, rifle racks, miscellaneous small fittings in crew's accommodation, wash-places, galleys, pantries and store rooms, renewing ribs of chequered plating to avoid scrapping the plating, aerial tubes, food lifts telephone cabinets.

Superstructure of a destroyer.

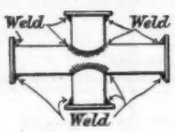
TABLE G.

ENGINE ROOM GIRDER.



Angles to girders were assembled in place. The ends mitred and welded, thus saving smith's work.

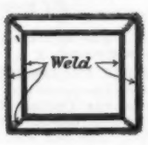
4 WAY PIECES.



Flanges welded to pipes and four-way pieces made and welded.

ESCAPE TRUNK.

COAMING.



Trunks for escape welded at sides in two pieces.

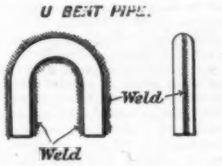
Coamings are assembled, angle bars mitred, and welded in place.

Thus leaving interior of the trunk free for access during the process, which would not have been the case had riveters been employed on the work.

The doors had to be cut to pass through hatchways. They were then welded together in place.

Protective doors to magazines.

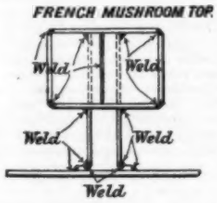
U BENT PIPE.



Method for making bends in pipes.

The two halves are stamped out in hydraulic press and welded as sketch.

FRENCH MUSHROOM TOP.



Method of making French mushroom tops totally by welding and then finally welded to deck.

BULKHEAD PIECE MAGAZINE SPRAYING.

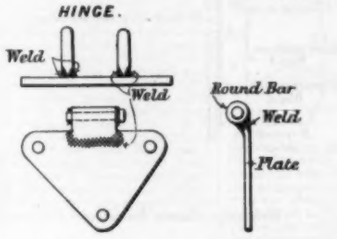
Method of making bulkhead pieces and deck pieces for magazine spraying.

Parts fixed together totally by welding as per sketch.

D.B.H.E.)

TABLE H.

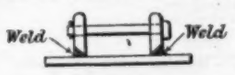
HINGE.



Lugs in female portion of hinge vead and welded to base.

Top of male portion also welded on.

SHOE FOR AWNING STANCHION.



Lugs for shoe bevelled (as sketch) and welded outside on to base.

SOCKET FOR STAY.

Socket for stay made by welding local thickening to thin plate.

(D.B.H.E.)

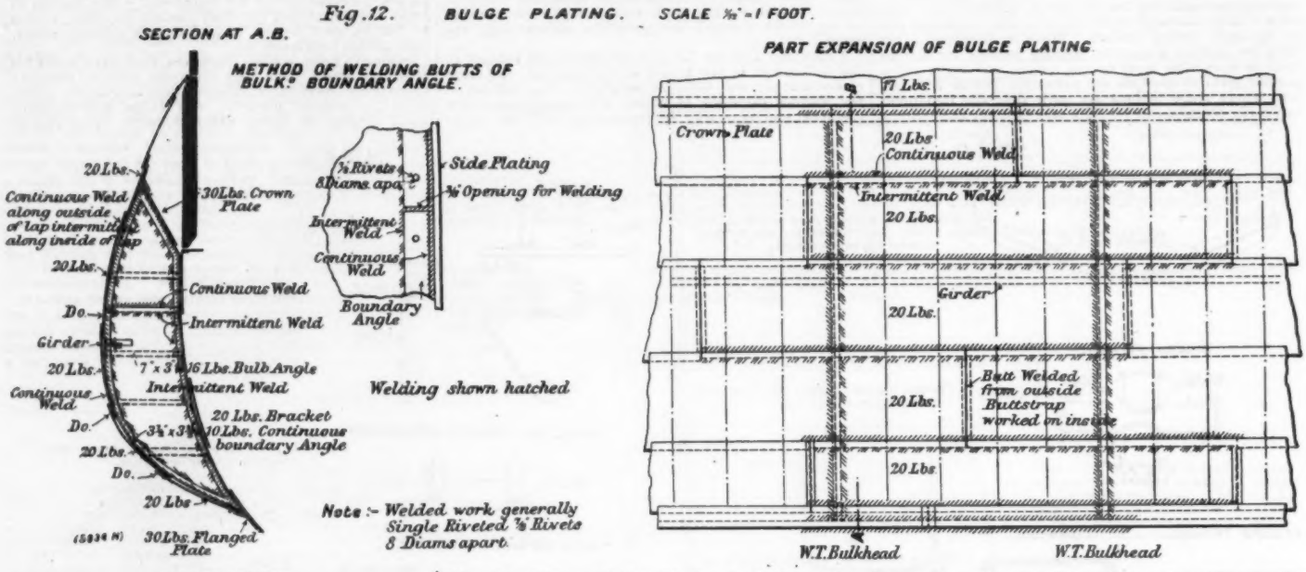
STATISTICS OF IRON AND STEEL PRODUCTION.

AN interesting series of tables giving the output of iron and steel in the principal countries of the world has recently been issued by the National Federation of Iron and Steel Manufacturers. It shows the output of pig-iron for the leading countries from 1900 to 1918 inclusive. In 1900 the United Kingdom produced 8,960,000 tons of pig-iron; the United States, 13,789,000 tons; Germany, 8,521,000 metric tons; and France, 2,714,000 metric tons. In 1918 the figures were: United Kingdom, 9,066,000 tons; United States, 39,052,000 tons; Germany, 11,590,000 metric tons; and France, 1,297,000 metric tons. The years of the largest output of pig-iron were the following: 1913, United Kingdom, 10,260,000 tons; 1916, United States, 39,435,000 tons; 1913, Germany, 19,292,000 metric tons; and 1913, France, 5,207,000 metric tons. The figures for the steel output in 1900 were United Kingdom, 4,901,000 tons; United States, 10,188,000 tons; Germany, 6,646,000 metric tons; and France, 1,565,000 tons. In 1918 they were: United Kingdom, 9,591,000 tons, including 306,851 tons of steel castings; United States, 45,073,000 tons; Germany, 14,874,000 metric tons; and France, 1,912,000 metric tons. The highest figures were reached in 1917, in the United Kingdom, with an output of 9,804,000 tons, including steel castings; in 1918, in the United States, with the above figure; in 1913, in Germany, with 18,959,000 metric tons; and also in 1913, in France, with 4,687,000 metric tons. Leaving out other minor countries, the pig-iron output of Belgium, which was an annual average of 2,183,000 metric tons for the four years 1910 to 1913, fell to 1,454,500 metric tons in 1914, being as low as 68,150 metric tons in 1915, and 127,825 metric tons in 1916. The steel production of Belgium, which was an annual average of 2,280,000 metric tons for the four years 1910 to 1913, was 1,360,000 metric tons in 1914, 94,500 metric tons in 1915, and 95,830 metric tons in 1916. Italy had for the five years 1900 to 1904 an average annual output of pig-iron of 44,680 metric tons, and an average annual output of steel of 163,000 metric tons; her corresponding figures for 1917 were, pig-iron 475,400 metric tons and steel 1,304,000 metric tons. The detail figures of pig-iron output for the United Kingdom for the year 1918 are as follow: Hematite, 3,547,804 tons; basic, 3,202,098 tons; foundry pig-iron, 1,272,288 tons; forge pig-iron, 777,704 tons; spiegel, ferro-manganese, ferro-silicon, &c., 246,943 tons; direct iron castings, 18,780 tons. In the same year there were produced in the United Kingdom: Bessemer steel ingots, acid 788,355 tons, basic 567,650 tons; open-hearth steel ingots, acid 3,901,136 tons, basic 3,924,415 tons; electric steel ingots, 103,201 tons; electric steel castings, 44,901 tons; Bessemer and open-hearth steel castings, 261,950 tons.

ELECTRIC WELDING IN WARSHIPS.

(For Description, see Page 25.)

Fig. 12. BULGE PLATING. SCALE ½" = 1 FOOT.



CATALOGUES.

Parachute.—The construction and working of the Calthrop parachute is described in a foolscap book of 78 pages issued by E. R. Calthrop's Aerial Patents, Limited, Eldon-street House, E.C. 2. There are many excellent pictures and diagrams, and a comprehensive reprint of press notices.

Monorail Hoists.—The travelling hoist with electric drive and travelling on single or double overhead rails has been very fully developed by the Shepherd Electric Crane and Hoist Company, Montour Falls, N.Y., U.S.A. Their catalogue is one of the best of its kind in clearness of description, lavish illustration and variety of machines presented.

Electric Cables.—Main cables for high and low tension power supply and telephone service form the subject of a special catalogue issued by Messrs. Johnson and Phillips, Limited, Charlton, S.E. 7. The arrangement of the cores, sheathing, insulating, shielding for various conditions, and jointing and laying are all clearly dealt with in the text and amply illustrated.

Filter.—A machine for filtering feed water and extracting grease is described in a catalogue from the Griscom-Russell Company, 90, West-street, New York. The vessel works under a maximum pressure of 250 lb. per square inch, and the true standard sizes made have filtering areas of 1,000 sq. in. to 30,000 sq. in., the water passed ranging from 800 gallons to 39,000 gallons per hour.

Conveying Machinery.—A carefully designed conveying plant is described in a book catalogue received from the Jeffrey Manufacturing Company, Columbus, O., U.S.A. Buckets are continuously carried on chain or link gear, vertically or horizontally as required, throughout a building. The buckets swing to level at all movements and are automatically tipped and returned for filling. All the gear is described in detail.

Concrete Mixer.—The British Steel Piling Company, Billiter-street, E.C. 3, send a catalogue of their concrete-mixing machine for ½ cub. yard charges. It is a revolving drum with fixed wings or scoops of special shape to turn over and mix the concrete in a regular way. A water tank with capacity graduations is fixed to the machine, which is mounted for belt drive or with portable engine. The company also send a "service" booklet stating terms, &c., on which they supply piling plant to contractors.

Steam Superheaters.—The Foster superheater is dealt with in full detail in a catalogue issued by the makers, the Power Specialty Company, New York. The superheater is made in forms suitable for marine, stationary and locomotive boilers. The heaters are seamless steel tubes covered with cast-iron rings having regular fins; these are bored and shrunk on. The company has opened a London office, for European business, at 315, Oxford-street, W. 1.

Boilers.—The types of land boilers made by Messrs. Holdsworth and Sons, Limited, Leeds-road, Bradford, are given as: Cornish, Lancashire, Cornish-multi, Yorkshire and Vertical. Each of these is made in a full range of standard sizes, of which tabulated particulars are given. The Yorkshire boiler is similar to the Lancashire, but shorter in proportion to its diameter and with furnace flues tapering in the reverse direction; the Yorkshire being appreciably larger at the back. Test and opinion indicate that considerable fuel economy is obtained by these differences. The catalogue mentions that a Lancashire boiler made by this firm in 1869 is still in service in the Bradford district.

Auxiliary Haulage.—Some very sturdy and compact hauling engines are shown in a catalogue from Messrs. Hugh Wood and Co., Limited, Newcastle-on-Tyne. There are 10-h.p., 15-h.p., 25-h.p. and 50-h.p. haulers each with single or double drums and electric motors complete and low built on frames. Also haulers on similar lines for endless ropes; and a series of steam-driven haulers. The smaller has two oscillating cylinders of 5 in. diameter and 8 in. stroke, developing up to 20 brake horse-power at over 270 r.p.m., and others up to 54 h.p. The steam pressure in all these is 60 lb. These haulers are extensively used about mining districts, and the firm also make a pneumatic pickaxe and a coal-cutting machine. This survival of the oscillating cylinder is interesting.

Marine Tail Shaft Lubrication.—The tail shaft bearing made by the B. R. Vickers (Leeds) Engineering Company, Limited, is described in a special catalogue. The bearing is carried in a tube which extends from near the propeller boss to a short distance from the coupling, giving an ample space for oil which is supplied by gravity feed. The sea end of the tube carries a rubber composition washer flared outwardly to exclude marine water, a felt washer to retain the oil and metal rings revolving with the shaft. The inner end of the tube has a neck bush bearing and a brass gland. A slight flow of oil to the sea ensures that there is no inflow of water or sand. Records of good results over several years are given on a number of shafts from 8 in. to 13 in. diameter; these also show the wearing virtues of cast-iron bearings when properly lubricated.

Power Transmission.—A bound catalogue of over 800 pages octavo from Messrs. Crofts (Engineers), Limited, Bradford, deals entirely with transmission fittings, appliances and machines. Nearly every page is illustrated and fully detailed tables of sizes and prices are given for each item. The sections cover shafting, bearing blocks, brackets and fittings of all kinds, counter-shafts and belt-shifting gear, belt pulleys, rope pulleys, tooth gear, chain gear, belting, ropes, lubricators, and a special final section of about 70 pages of "sundry tables." The whole contents are strictly relevant to the transmission of power. Many special inventions and designs of undoubted merit are shown. The aim of the firm is to supply every necessary item for fitting up this branch of equipment and to give all the required technical information in practical form. This catalogue will be a real help to every factory and workshop staff, both as a catalogue and as a reference book.

Drilling Machines.—The radial drilling machines shown in a catalogue received from Messrs. James Archdale and Co., Limited, Birmingham, form an interesting contrast to the earlier types of these machines. All the gear is carried on a substantial pillar, the arm is a box-casting of great strength and stiffness and swing for the full circle, the machined base plates extend in one, two or three directions in the different types, the intermediate tables have machined and bolt slotted surfaces on sides as well as top and there are swivelling and universal tables on which the work-piece can be readily set and firmly held at an angle. In addition to these features which vastly increase the convenience and range of the machines the controls are so centralised that a man can reach all easily. The motion of a single constant speed belt, or electric motor, is transformed by gearing to a wide range of speeds and feeds. This catalogue is devoted to numerous variations in size and range of work; but all founded on the same essential principles of construction.

Unit Building.—Engineering firms are taking a more direct interest in the question of building cottage houses; amongst them the Crittal Manufacturing Company, Limited, Braintree, Essex, which has issued a booklet on the subject. This firm was concerned in many works of rapid building during the war. A unit system is proposed under which building blocks, casements, doors, &c., would be made to a standard (metre or yard). The buildings would vary in size by this unit, and architects, builders and makers of wood and metal fittings would make to standards based on this unit. The estimated, saving in cost of construction is 25 per cent. to 30 per cent., just about the difference which would make impossible schemes into possible ones. Steel would be largely used in place of wood for casements, doors and other parts, suitable forms being made by special rollings, pressings, and other processes which become extraordinarily cheap when very large quantities are used. Apart from saving in actual cost of material, wages, &c., there would be the advantage of reliable supplies, of house "parts" consistent in quality and exact in size. We are pleased to see that the Crittal Company worked in co-operation with the Winget Company, which makes special machinery for producing standard building blocks, or slabs, and would be glad to see other engineering firms join in considering this question; private enterprise might in these huge tasks develop a system of combined work which would be more hopeful than Government action. The "sample" houses are, it must be noted, much more substantial throughout than the prevailing type of cottage, and the system would as easily allow of a somewhat less rectangular appearance.

IMPORT OF DYESTUFFS.—The Board of Trade issued, on the 19th inst., an announcement dealing in detail with the import of dyestuffs. Firms desiring full information on the subject, or wishing to make application for an import licence are advised to communicate direct with the Secretary of the Licensing Sub-Committee, 53, Spring Gardens, Manchester.

REMOVAL OF NITROGEN FROM MOLYBDENUM FILAMENT BULBS.—Irving Langmuir finds that, when molybdenum filaments are heated to 2,000 deg. or 2,400 deg. C. absolute in nitrogen at very low pressure (0·03 mm.), the filament loses weight at the same rate as if it were heated in a vacuum, while nitrogen disappears; yet the amount of Mo lost is much greater than the nitrogen which is thus "cleaned up." The removal does not succeed in the presence of traces of water vapour. The ratio of the number of nitrogen molecules removed to the atoms of Mo evaporated is independent of the gas pressure (if very low), but decreases with rising temperatures. Two compounds, NMoN and Mo : N_2 seemed to be formed by the collisions between the molecules and atoms near the filament. The deposit settling on the bulb is spongy and can easily be rubbed off, whilst the deposits obtained in vacuum bulbs can scarcely be scratched off with a knife. When the bulb has been cooled in liquid air, the deposit gives off some nitrogen on being heated to ordinary temperature subsequently, and readsorbs part of the nitrogen on recooling; hydrogen is hardly adsorbed. The deposit decomposes water vapour at ordinary temperature. These reactions (Journal of the American Chemical Society, 1919, pages 167 to 194) exemplify the complexity of the reactions in vacuum bulbs.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in Italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-Lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

AGRICULTURAL APPLIANCES.

123,847. The Austin Motor Company, Limited, Northfield, Birmingham, and Sir H. Austin, Northfield, Birmingham. Agricultural Tractors. (2 *Figs.*) March 14, 1918.—According to this invention, the engine case and change-speed gear-box are of tubular and substantially cylindrical construction, the engine case being removable as a unit from the change-speed gear-box, and the change-speed gear-box being removable as a unit from the driving axle-case, the engine-case, change-speed gear-box, and driving axle-case constituting the main structure of the tractor frame. The main structure of the frame is made up of the engine-case A, change-speed gear-box B, and driving axle-case C. The engine-case is tubular and substantially cylindrical, and is fixed to the change-speed gear-box, which is also tubular and substantially cylindrical, and is removable as a unit therefrom. The gear-box B is fixed to the driving axle-

Fig. 1.

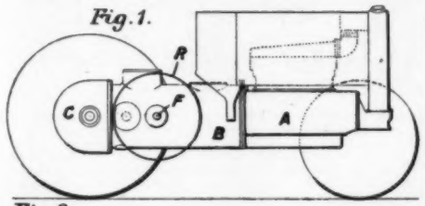
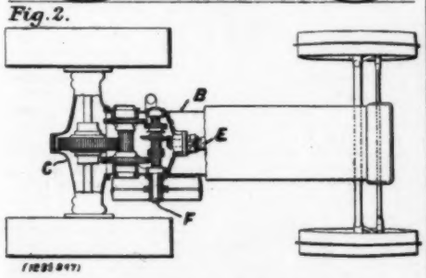


Fig. 2.



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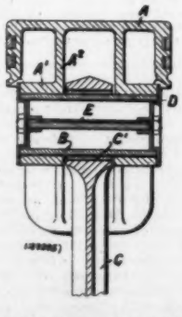
case C and the change-speed gear-box B, together with the change-speed mechanism, may be readily removed as a unit from the case C. The clutch shaft E drives a first intermediate shaft F, which is carried in bearings of the sides of the change-speed gear-box B. The shaft F lies transversely of the tractor and carries movable change-speed gear wheels. A second intermediate shaft G, which is parallel with the shaft F and conveniently in the same horizontal plane therewith, carries fixed wheels of the change-speed gear and the pinion for the final drive, the teeth of this pinion being, conveniently, cut in the periphery of the shaft. The first intermediate shaft F extends beyond the bearing at one side of the change-speed gear-box, and carries pulley R from which an independent machine such as, for instance, a threshing machine or chaff-cutter, may be driven. (*Sealed.*)

GAS ENGINES, PRODUCERS, AND HOLDERS, &c.

123,805. R. W. Maudslay, Coventry, and The Standard Motor Company, Limited, Coventry. Gudgeon Pins. (1 *Fig.*) March 1, 1918.—This invention relates to improved means for securing the gudgeon pins of pistons. According to



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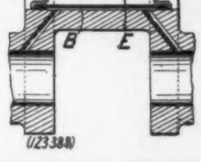
this invention, means for securing the gudgeon pins of pistons comprise a screwed bolt to extend lengthwise through the gudgeon pin and receive discs which clamp the ends of the said gudgeon pin and extend beyond its periphery to lie over and engage the outer ends of its housing. The bosses A1 for the gudgeon pin B are supported at their inner ends by webs A2 integral with the piston A. By this means a recess is made in the piston walls at the outer ends of the bosses without weakening their means of support. The outer ends of the bosses A1 are rendered accessible by the removal of the portions of the skirt of the piston A to which the bosses are usually joined. The gudgeon pin B is rotationally free in either the bosses A1 or the bearing C1 of the connecting rod C, or in both. Discs D, having bosses which extend into and fit the bore of the gudgeon pin B, to locate them thereon, are provided at each end of the latter, and a bolt E extends through them and the gudgeon pin to clamp them against the ends thereof. The faces of the disc D extend beyond the periphery of the gudgeon pin to lie over the outer ends of the bosses A1, sufficient clearance being provided by the length of the gudgeon pin to prevent the bosses being strained endwise when the bolt E is screwed up. (*Sealed.*)

123,388. H. R. Ricardo, London, and Sir W. G. Armstrong, Whitworth and Co., Limited, Newcastle-on-Tyne. Engine Crankshafts. (1 *Fig.*) February 19, 1918.—This invention relates to engine crankshafts of the type which is formed hollow, not only as to parts of the shaft itself but also as to the crank-pins. According to this invention, in each hollow part of the shaft or pin which forms, or is carried, in a bearing, there is disposed a tube B, the external diameter of which is less than the internal diameter of the hollow in the crankshaft part, and the ends of this tube are bevelled off or coned externally. Two rings C are provided, each of which is externally cylindrical, of such a size as to closely fit the hollow crankshaft part, while the interior of each ring is coned as so to adapt it to fit on the end of the tube. The two rings C are drawn towards each other and on to the ends of the tube by end plugs D, D1 and a central bolt E. Each ring thus forms a tight joint between one end of the tube and the surrounding wall of the crankshaft part. The tube B with the end rings thus constitutes an annular chamber lining the hollow crankshaft part, and the passages for the inflow and exit of lubricating oil lead into this annular chamber.



(123,388)

It is then only necessary for this chamber to be filled with oil, which forms a layer or relatively thin cylinder within the crankshaft part in place of the solid mass of oil which in existing constructions is required to fill the hollow part of the crankshaft. The quantity of oil carried in the shaft is thus materially reduced. The inner tube is conveniently formed of steel, while the end rings may be constructed of white metal, fibre or other suitable metal or material adapted to be pressed into place in the desired manner and make the necessary joints. Each end plug D, D1 is conveniently constructed as a cap comprising a disc with a peripheral cylindrical part and an outwardly-directed flange. The disc and cylindrical part of the cap fit within the end of the tube, while the flange will bear against the locking ring. In the centre of the plug or cap is a hole through which can be passed the bolt E, which extends right through the hollow part of the crankshaft and through the opposite end cap, a nut being there screwed on to the end of the bolt so that the two caps can be drawn together and the rings thereby forced on to the ends of the tube and jammed between these ends of the surrounding wall of the hollow crankshaft part. (*Sealed.*)

123,402. Swan, Hunter and Wigham Richardson, Limited, Walker, Newcastle-on-Tyne, and M. O. Wurl, Newcastle-on-Tyne. Pistons. (3 *Figs.*) February 21, 1918.—This invention relates to the construction of pistons for internal-combustion engines of the kind in which, for the purpose of facilitating the withdrawal of the piston rings, the piston or part of the piston carrying the rings is secured by bolts accessible from the combustion space. According to this invention, bolts are employed which, while accessible from the combustion space, are separted from direct contact with it by removable protecting members. A is the hollow piston body, through which cooling water may circulate. B is the piston rod. C is the head of the piston. D are the piston rings on the head C. E is one of the screws or tap bolts connecting the head C to the body A. F are

Fig. 1.

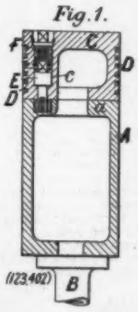
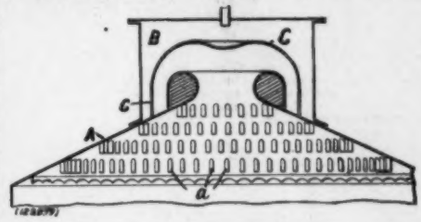


Fig. 2.

(123,402)

protecting plugs. In the construction shown, the piston body A is separate from the head C and is provided at its upper end with a flange *a*, into which the tap bolts E take, the bolts being inserted through deep recesses in internal lugs of the piston head, the head of each bolt being formed with a square end for operation by a spanner. Each recess is tapped to receive a screw plug F, having a square end lying within the upper part of the recess. Small springs between and above the plug F act to prevent the slackening of the bolt and plug. As the tap bolts are separated from the combustion space at the end of the piston by the plugs they are prevented from overheating, the cooling fluid in the interior of the piston head keeping the bolts fairly cool, and so avoiding any risk of spoiling the joint by expansion of the bolts. (*Sealed.*)

123,879. J. H. Dent, Liverpool, and The United Alkali Company, Limited, Liverpool. Gas Scrubbers. (4 *Figs.*) April 18, 1918.—The apparatus, according to this invention, is designed to utilise the surface tension of liquids. The apparatus comprises a cone with a number of projections on its underside, and has the apex removed and the upper part rounded, the rounded portion being surrounded by a trough in which is a dome preferably having a depressed upper part and openings around its bottom edge, which is immersed in liquid in the trough to prevent the escape of gas by the liquid luting the said openings. The cone A has a number of projections *a* from its underside. The apex of the cone is absent and the edge rounded as shown, this rounded



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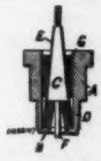
portion being surrounded by a trough B in which is a dome C, shown as having a depression in its upper part and openings *c* around its edge which is immersed in liquid, which is maintained at a sufficient level in the trough B to constitute a luting to prevent the escape of gas through the openings *c*. The liquid to be distributed is fed into the depressed part of the dome C and passes into the trough B and through the openings *c* in the dome C, and thence over the rounded upper edge of the cone A and the liquid spreads over the inner side of the cone A and drips from the projections *a* on the underside thereof, which projections *a* are preferably disposed to give practically uniform distribution of the liquid. (*Sealed.*)

123,917. B. Hoppe, Rugby, A. M. Lodge, Rugby, and The Lodge Sparking Plug Company, Limited, Rugby. Sparking Plugs. (6 *Figs.*) June 25, 1918.—This invention has for its object to construct improved sparking plugs for internal-combustion engines. In carrying the invention into effect, a metal body A is formed with a cylindrical chamber which has an inwardly projecting shoulder B at its inner end. This shoulder may be formed integrally with the body or it may consist of a separate plate secured to the body. The central electrode C is made for the greater part of conical form, the larger end being at or near the inner end of the plug. At the larger end of the electrode a bush D of mica washers is provided, the bush being tapered internally and externally. Around the electrode and bush is arranged a mica wrapping E. To the larger end of the electrode is



attached a stem F which passes axially through the mica bush, suitable clearance or space being provided between the stem and the inner surface of the bush. Over the wrapping above-mentioned is placed an aluminium or other metal sleeve G which internally is tapered to correspond with the taper of the wrapping and inner electrode, and externally is cylindrical. The composite structure is inserted in the metal body, the lower end of the mica bush resting on the internal shoulder at the inner end of the body, and the metal sleeve is forced inwards under pressure to produce the required gastight joint. The sleeve is held in position by an outer collar screwed into or over the body, or by turning the upper end of the body over the sleeve. The projecting end of the central electrode may be enclosed by a detachable insulating cap. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

123,907. Guest, Keen and Nettlefolds, Limited, Birmingham, and T. W. Eayrs, Smethwick, near Birmingham. Capstan and Turret Lathes. (4 *Figs.*) June 5, 1918.—The invention consists of improvements in or the setting of box tools such as are used in automatic machines, capstan and turret lathes and screw machines. According to the invention, there is employed in conjunction with the box tool when setting the parts of the same a two-part sitting device, one of the parts of the setting device consisting of a bush, the external diameter of which is such that it accurately fits the hollow shank of the box tool, the bush being of such a diameter internally that it will accommodate an accurately fitting rod constituting the other part of the device which is of the exact diameter of the rod to be produced by the box tool when the same is at work in the machine with which it is used. A is the bush which is fitted in the hollow shank C of the box tool and which is temporarily

Fig 1.

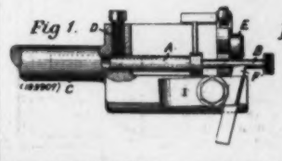


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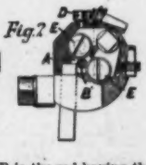
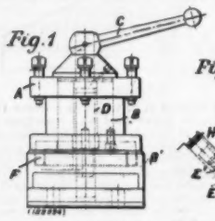
Fig. 2.

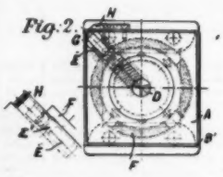


secured therein by the set screw D, and B is the rod having the diameter to be produced in the wire or rod to be operated on by the box tool when in the machine. The bush A has an axial hole in which the rod B accurately fits. The bush A selected having been fitted in the hollow shank C of the box tool, it is fixed therein by the set screw D. The rod B constituting the other part of the setting device and which has the exact diameter to be produced in the rod or wire to be operated upon is fitted in the bush *a* so as to leave the head (or T-shaped end) projecting beyond the roller steadies E, E and the cutter proper F of the tool. The steadies E, E having been adjusted so as to bring them into bearing contact with the pin or rod B of the setting device, as is illustrated in Fig. 2, they are fixed in their adjusted positions by the means ordinarily employed. The cutter F is then adjusted so as to bring its acting part or point into intimate contact with the

pin or rod B, as is seen in Fig. 2, and it is then fixed by the usual fixing screw pins. The pin B is then removed from the bush A, and the bush is afterwards removed from the shank C of the box tool, which can now be applied to the machine in which it is to be used. (*Sealed.*)

123,934. **G. H. Smith, Bredbury, near Stockport, and Pollock and Macnab, Limited, Bredbury, near Stockport. Tool Holders.** (3 *Figs.*) October 9, 1918.—This invention relates to tool holders for lathes of the type in which the tool holder or tool post is adapted to be revolved on a fixed stem and is provided with indexing and positioning devices. The square tool post A is mounted on the fixed stem B, which is solid, or in one piece with the base B1. The handle C to effect the locking of the tool post and also the withdrawal of the index plunger, is fixed to the upper end of the locking screw D. The index plunger E has a bevelled inner end adapted to enter a lateral aperture in the screw D and be engaged by a bevelled surface thereon. The index ring F may be made solid or in one piece with the tool post A, or made separately and secured to the post. The spring G serves to force the plunger E inwards to its engaging position; the outer end of such spring abuts against the retaining plate or bracket H. The index plunger E is shown in

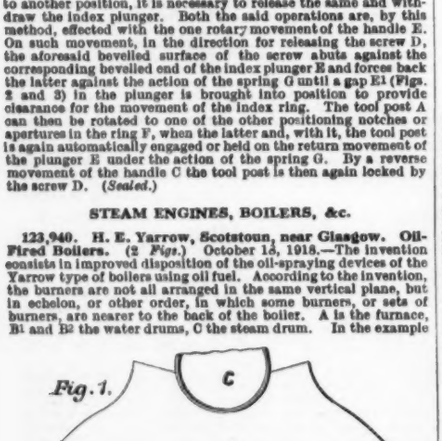


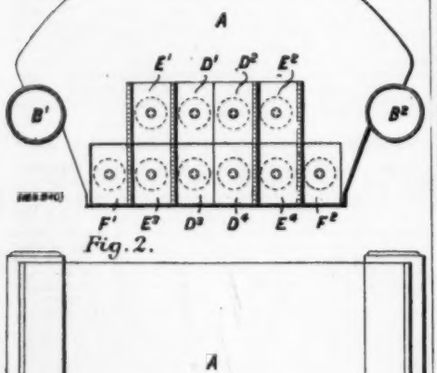


engagement with one of the four positioning notches or apertures in the index ring F, at which position the tool post is held by the locking screw D in the known manner. To rotate the tool post to another position, it is necessary to release the same and withdraw the index plunger. Both the said operations are, by this method, effected with the one rotary movement of the handle E. On such movement, in the direction for releasing the screw D, the aforesaid bevelled surface of the screw abuts against the corresponding bevelled end of the index plunger E and forces back the latter against the action of the spring G until a gap E1 (Figs. 2 and 3) in the plunger is brought into position to provide clearance for the movement of the index ring. The tool post A can then be rotated to one of the other positioning notches or apertures in the ring F, when the latter and, with it, the tool post is again automatically engaged or held on the return movement of the plunger E under the action of the spring G. By a reverse movement of the handle C the tool post is then again locked by the screw D. (*Sealed.*)

STEAM ENGINES, BOILERS, &c.

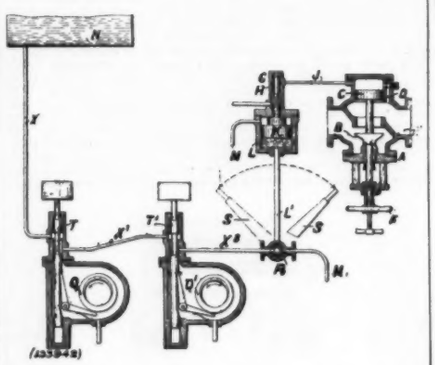
123,940. **H. E. Yarrow, Scotstoun, near Glasgow. Oil-Fired Boilers.** (2 *Figs.*) October 15, 1918.—The invention consists in improved disposition of the oil-spraying devices of the Yarrow type of boilers using oil fuel. According to the invention, the burners are not all arranged in the same vertical plane, but in echelon, or other order, in which some burners, or sets of burners, are nearer to the back of the boiler. A is the furnace, B1 and B2 the water drums, C the steam drum. In the example





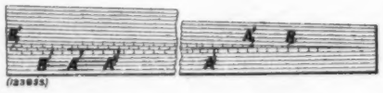
shown there are 10 burners, 6 in the lower set and 4 in the upper. Burners F1, F2, are placed in the usual position at the front of the boiler, burners E1, E2, E3, E4 are arranged in a vertical plane nearer to the back of the boiler and burners D1, D2, D3, D4 in a plane still nearer to the back of the boiler. The burners are symmetrically disposed with relation to the central line of the boiler, those nearest to the back of the boiler being placed closest to the central line. (*Sealed.*)

123,942. **Scotts' Shipbuilding and Engineering Company, Limited, Greenock, and J. F. Anderson, Greenock. Steam Turbines.** (1 *Fig.*) October 22, 1918.—This invention provides automatically acting cut-out gear which will, in certain emergencies, shut the steam off the turbines. The gear is characterised by an actuating valve which depends, for its action, upon the oil pressure in the forced lubrication system, this actuation valve controlling a self-acting emergency valve capable of shutting off the steam supply to the turbines. The steam emergency valve A is arranged at the boiler side of the regulating valves and has a valve B on a spindle which also carries a piston c. The area of the piston is in excess of that of the valve, so that the latter cannot open under pressure of steam entering at A1 until the pressures at both sides of the piston C are equalised, this being done by the passage of steam through a small by-pass port D, the outlet of which is controlled by means of a pin valve. When the pressures are equalised, the valve B opens to the extent permitted by the hand wheel F. To automatically close the valve B it is only necessary to connect, by pipe J, the space at the upper-side of the piston C to a point of lower pressure so that the unbalanced pressure on the underside will at once raise the piston and close the valve in well-known manner. The actuating valve G, consists of a sleeve valve H which, when in the upper position, closes the connection J and, when in the lower position,



opens the connection. Secured to the lower end of the spindle of the valve H is a heavy ram K which works in a separate cylinder L to which oil from the forced lubrication system enters by means of a pipe L1, and the actuating valve H is normally retained in its upper position by the pressure of the oil acting on the underside of the ram. The space at the upper side of the ram is connected with the oil drain tank by means of the pipe M. The area and weight of the ram are so proportioned that it continues to be supported by the oil pressure until, from any cause, the pressure falls below a predetermined limit. Whenever the oil pressure is reduced below the limit the ram immediately falls and moves the actuating valve H to its lower position, thereby opening communication between the upper side of the piston C and the hot well tank, thus causing the emergency valve B to close automatically and shut off the steam into the turbines. The oil supply for the cylinder L comes from the forced lubrication system direct or from the gravity tank N and pipes X, X1, and passes through the valves T, T1, controlled by the governors Q, Q1, of the high pressure and low-pressure turbines, and thence through pipe X2 and switch cock R to the pipe L1. (*Accepted March* 19, 1919.)

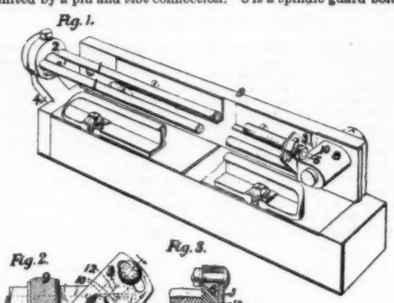
123,855. **The Chimney Construction and Boiler Setting Company, Limited, Westminster, London, and F. B. Hamilton, Brighton. Chimney Stacks.** (3 *Figs.*) March 20, 1914.—The invention relates to chimney stacks, with spiral bonds or courses, and the invention consists broadly in building up the initial spiral and terminating the final spiral by means of alternate inclines of cement and of bricks suitably tapered, each of such inclines forming a sector of the circumferential wall of the chimney in such a manner that an initial complete spiral can be obtained as a starting base and the top of the chimney finished off square. In accordance with the invention, the spiralling is started by laying an inclined sector or part of a spiral A in cement, proceeding from a knife-edge A1 at its point of inception to a height or thickness of about 2 in., *i.e.*, something less than the thickness of a standard brick. From this point the spiral is continued by another adjoining inclined sector or part of a spiral B which, however, is formed of tapered bricks, it being understood that the first brick abuts at one end against

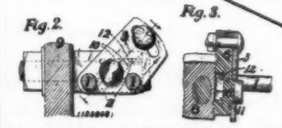


the thick end of the cement wedge and the subsequent bricks gradually thicken until the last tapered brick B1 of the section is of standard thickness at the extremity of the incline. That is to say, the first brick incline or sector of the spiral joining to the first cement incline or sector makes a rise from the knife-edge at the point of initiation to the thickness of a standard brick. From this point another similar wedge of cement is laid, proceeding as before from a knife-edge to a height of about 2 in., and upon this a layer of standard bricks is laid, or alternatively the bricks can be laid first and the cement wedge formed on top of the bricks. This will bring the spiralling from its knife-edge at the point of initiation to a height of, say, 5 in.—3 in., the thickness of the brick, and 2 in. the thickness of the cement. The spiralling can now be continued with a course of two rows of brick, one being a row of standard bricks and the other a row of bricks cut on the taper so that the spiral will now proceed from its knife-edge to a thickness of, say, 6 in.—the thickness of two bricks. The process can now be repeated by laying two rows of bricks and a cement wedge—or *vice versa*—which will bring the spiral to a height of 8 in., then a course of bricks of which two rows will be standard bricks and one row will be bricks cut to taper slightly, which will bring the height to 9 in., then a course of three rows of bricks and a cement wedge, bringing the height to 11 in., and so on, so that when one complete circle of the stack has been finished a spiral will have been formed proceeding from a knife-edge to an ultimate height which can be in proportion to the circumference of the chimney. To finish off the chimney at the top the process will be reversed. (*Accepted March* 19, 1919.)

TEXTILE MACHINERY.

123,808. **A. Newton-Smith, Westminster, London. Picking Mechanism.** (3 *Figs.*) March 4, 1919.—In the picking mechanism of looms, in accordance with this invention, the picker carrying means are mounted at the ends in suchwise that the inner end (that is the end at or adjacent the reed) is capable of movement in an upward direction, either against the action of gravity or of resilient means, said upward movement taking place at the time that the shuttle is leaving the shuttle-box, and being caused by the pull of the picking strap on the picker. The picker is actuated by a tappet through intermediate mechanism of well-known character, and the tappet is such that the picker remains or dwells at the reed end of the shuttle-box after the delivery of the shuttle until the shuttle is returning from the opposite shuttle-box, when it (the picker) is caused to move with or in advance of the shuttle as it is boxed. The picker-carrying means comprises a pair of horizontal and parallel spindles 1 mounted at their ends in plates 2, 3. The plate 2 is carried by an arm 4 and is adjustable angularly in relation thereto, the extent of adjustment being limited by a pin and slot connection. The plate 3 is mounted on a block 5, and is adjustable angularly in relation thereto, the extent of adjustment being limited by a pin and slot connection. 8 is a spindle guard bolted

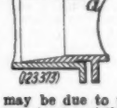




to the back plate 9 of the shuttle-box (or to the sword) and having on the side facing the shuttle-box a slot 10 that slopes downwardly and inwardly. The block 6, which is contained within the slot 10 and is an easy fit therein, is slotted at 11. 12 is a pin that extends across the slot 10 in the spindle guard 8 and comes within the slot 11 in the block 6. The block 6 is normally supported by the pin 12, which also acts as a stop to limit the movement of the block 6 in the groove or slot 10. The tappet which actuates the picking stick, picking strap and picker through intermediate mechanism of well-known character, is made so that the picker remains or dwells at the reed end of the shuttle-box after the delivery of the shuttle and until the return of the shuttle, when it is caused by the actuation of the picking stick by the tappet to move with or in advance of the shuttle, as it is boxed. When the picker is moved towards the reed end of the shuttle-box, the pull of the picking strap thereon causes the inner end of the picker-carrying means (spindles 1) to move in the direction of the slot in the spindle guard 8. During the dwell of the picker at the reed end of the shuttle-box, and until the next pick, the picker-carrying means resume a horizontal position parallel with the flyplate and with the box back. (*Sealed.*)

MISCELLANEOUS.

123,373. **J. Stone and Co., Limited, Deptford, and T. Drewry, Forest Gate. Expansion Joints.** (6 *Figs.*) February 16, 1918.—This invention relates to expansion joints of the type in which telescopic sleeves are employed for effecting pipe joints, the inner sleeve being internally of a gradually increasing diameter towards the end, so that, being relatively thin, it may be distended or expanded by the fluid pressure and hermetically seal the joint, while nevertheless permitting of the telescopic movement due to the expansion or contraction of the metal of which the pipes are made. According to this invention, and in order to obviate distortion of, or racking strains



in the pipes, which may be due to unequal expansion, contraction and vibration, or to any of these conditions, the inner sleeve or spigot *a* is slightly reduced in external diameter, except in the region of the internally tapered end of the spigot or inner sleeve, so that, in practice, the only part of the spigot in intimate contact with the outer sleeve *b* is that in the region of the internally tapered end of the spigot, and, if de-lired, a short distance beyond it. The end of the spigot is, in some cases, materially reduced in diameter before being made parabolic or other suitable curve, so as to provide the desired degree of flexibility without deleteriously affecting the strength of the sleeve. (*Accepted, March* 5, 1919.)

UNIVERSITY OF BRISTOL.—With the concurrence of the Society of Merchant Venturers, the council has appointed Major Andrew Robertson, D.Sc., to the vacant Chair of Mechanical Engineering. Professor Robertson was educated at the University of Manchester; he served his engineering apprenticeship in works at Fleetwood; in 1905 he graduated as B.Sc. with first-class honours in engineering; in 1909 he was awarded the M.Sc. Degree, and in 1915 the D.Sc. Degree. He has done a considerable amount of research work, some of which, however, has not yet been published, being connected with war engineering problems. He was a demonstrator in engineering in the University of Manchester and resident tutor of Dalton Hall from 1908 to 1912; Vulcan Research Fellow 1912–15; lieutenant in the R.N.V.R., 1915, and for some time has been head of the Mechanical Testing Laboratory for the R.A.F. at Farnborough. The present occupant of the chair, Professor John Munro, has been granted the title of Emeritus Professor in Mechanical Engineering.